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DISTRIBUTION OF MOLLUSK SHELLS IN THE SEDIMENTS OF FLORIDA BAY

by

Alan B. Shaw

Paleontological Research Institution
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FOREWORD

BY BRIAN F. GLENISTER

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Oil company interest in biofacies/lithofacies trends in the Holocene carbonates of South Florida began in the late 1950s, initiated by Shell Oil Company. Alan Shaw participated in many of these early field trips, and began his own research program after he joined Amoco Production & Research. The primary purpose was to provide a modern analog that would serve in prediction of facies relationships (*i.e.* of hydrocarbon source to reservoir) in ancient sediments. Mollusca—Gastropoda and Pelecypoda—were determined to be the most useful group in reflection of South Florida facies trends. Other groups, however, such as Brachiopoda, proved to display similar trends in ancient analogs, and the classic mantra "size, abundance, diversity" applies to all. That is, whether it is in the Holocene of Florida Bay or Midwestern U. S. Ordovician limestones, given an unstably hostile environment, there will be few species, small size is dictated by environmental fluctuations, and available resources can support large numbers of specimens.

The first of a yearly succession of Amoco South Florida seminars occurred in 1964. Each subsequent year, up to 25 senior industry explorationists from around the world assembled in the Florida Keys for a five-day traverse from the fresh-water Everglades, across Florida Bay to the open water Reef Tract. The purpose was to demonstrate the logic and predictability of facies distributions, and to discern the economic implications of facies analyses. Participants returned one month later for the Seminar Ancient Phase, a 1,400 mile traverse of Mississippian carbonates, from western Illinois to northern Montana, by helicopter, fixed-wind aircraft, bus, and van. The purpose was to gain recognition that facies trends seen in Florida are paralleled in ancient carbonates.

The Amoco Seminar ended in 1983. The Department of Geoscience of the University of Iowa, however, continued to offer South Florida seminars for students plus U. S. and foreign guests until 1997. Florida facies analysis remains a significant element of the Geoscience curriculum at Iowa and several other American universities.

The collections and data from the entire Amoco Seminar are now reposited at Iowa, representing an investment of 25 person-years and $1.5 million. It includes 465,000 identified Florida specimens, representing 300+ species from 300+ localities. These collections and data are the basis for the present volume.

It is important to understand what Shaw's work is and what it is not. This is not a study of living mollusks in their environments, but a study of shells in sediments. Biological nomenclature in Shaw's work was designed to communicate morphologic groupings that could be readily recognized by Seminar participants, rather than focusing on the evolving complexities of formal taxonomy. His goal was to recognize sedimentary rather than biological assemblages. Biologists using these data may therefore find that they only partially reflect the living distribution of the animals. That is part of the point. Dr. William B. Lyons, of the Florida Marine Research Institute, has kindly recommended the following taxonomically focused references on the South Florida biota as a supplement to Dr. Shaw's data: Turney and Perkins (1972); Mikkelsen and Bieler (2000); and Brewster-Wingard *et al.* (2001).[1]

Shaw's work was enormously influential and successful. Explorationists still use the Florida model to determine where they can anticipate hydrocarbon production from reservoir facies such as reefs or lime sands. An example is the Carboniferous production along the flanks of the northern Rocky Mountains. After all, if you are spending $50–150 million on a single well, you need to utilize all available help!

Alan Shaw is perhaps best known among geologists and paleontologists for his theoretical work in biostratigraphic correlation, codified in his famous volume *Time in Straitigraphy* (1964). But he was also a master carbonate geologist and paleoecologist of the classical sort. I and all who know the value of this area of Alan's work are thus very pleased that the present volume (and accompanying data) have finally been made available to a wider readership.

[1] Editor's Note: For an updated version of Mikkelsen and Bieler (2000), see Bieler and Mikkelsen (2004). Many of the taxonomic names and species concepts used in the present monograph have changed since the research was conducted; although no attempt has been made to update these epithets, the text-figures herein are sufficient for the reader to make adjustments. For current taxonomy, see Mikkelsen and Bieler (2004) and Rosenberg (2005).

DISTRIBUTION OF MOLLUSK SHELLS IN THE SEDIMENTS OF FLORIDA BAY

Alan B. Shaw
210 Kamira Drive, Kerrville, Texas 78028, U.S.A.

ABSTRACT

The distribution of the shells of 336 taxa of gastropod and pelecypod mollusks in sediments of Florida Bay is described, based on analysis of 321 samples (containing more than 540,000 individual specimens) collected between 1964 and 1983. These data were collected to determine biofacies as defined by shells enclosed in carbonate sediments as a means for solving geologic problems of petroleum exploration. Taxa used are not directly comparable to Linnaean taxa, but rather are operationally-defined for recognition by non-specialists. Dominance of samples by a few taxa made it possible to identify biofacies in the field. The composition and geographic distribution of the resulting 14 biofacies are summarized. All of the project's data are presented on the accompanying CD-ROM.

INTRODUCTION

This paper is based on a study of the molluscan fauna of Florida Bay and the adjacent reef tract (Text-fig. 1) begun in 1964 as part of carbonate seminars developed by Pan American Petroleum Co. (later, Amoco Production Co., later BP Amoco) for its Exploration personnel. The seminars were designed to acquaint Amoco geologists, paleontologists, and other personnel with the conditions under which calcium carbonate sediments develop.

Large areas of Florida Bay are filled by fine-grained limy sediments that are difficult to subdivide on physical bases alone. Therefore we needed a field technique that could be used to provide usable subdivisions of these "muds" in the field. The criteria for a workable field tool were that the organisms:

1) were abundant throughout the Bay;
2) yielded hard parts;
3) were large enough to be seen in the field;
4) were simple enough to be learned easily;
5) were diverse enough to provide usable subdivisions of muddy areas; and
6) were sessile so that their remains accumulate primarily where they live.

The reader should keep in mind the underlying geologic and paleontologic purposes of this study. We wanted to discover what principles the Florida mollusks could reveal that might serve in making environmental interpretations of the ancient fossiliferous rocks that the Amoco geologists and paleontologists studied as part of their daily business. In addition, the permits under which we collected forbade the collection of living specimens so we took only skeletal remains that would likely be preserved as fossils.

Given our requirements, we did not consider soft-bodied organisms, because they would not leave fossils. Of the many organisms that leave skeletal parts, most did not meet all of our criteria. Foraminfera and Ostracoda are abundant but too small to be of practical use to field seminar groups. Bryozoa have skeletons, but they are absent in much of the northern and interior parts of the Bay. Corals are abundant on the reef tract, but they reach only a short way into the Bay.

Only the Pelecypoda and Gastropoda met all of our requirements. Chitons and scaphopods are not widely enough distributed to be of use in the field, but, being mollusks, they have been included in the statistical samples. The pioneering work of Turney, done in 1958 and published in 1972 (Turney and Perkins, 1972), showed that the clams and snails are distributed in an understandable manner. The present study extends and refines the basic patterns recognized by Turney.

Our objective was therefore to define the molluscan biofacies of Florida Bay quantitatively. If we could do this, we could quickly teach the seminar participants to identify the shells they needed to recognize the biofacies for themselves.

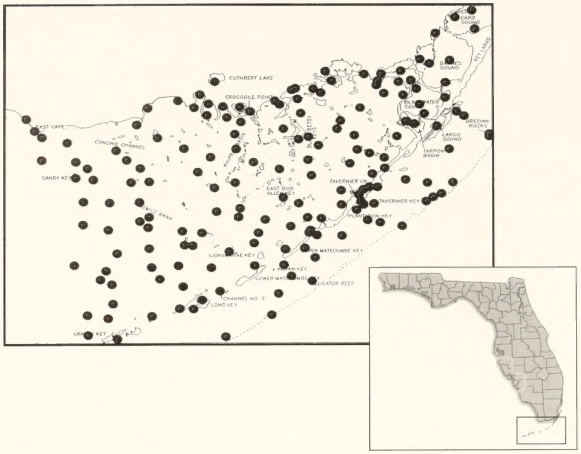
ACKNOWLEDGMENTS

At the end of the 38 years during which I have worked on this study I find it difficult to recall with complete certainty everyone who has contributed to my understanding of Florida Bay. But I shall try.

The first person to whom I am indebted, for introducing me to the many fascinations of Florida Bay, is Robert N. Ginsburg. His Shell Oil Co. field trip of 1956 opened up this new world to me and provided insights for all of my subsequent work both as a paleontologist and as a stratigrapher.

A considerable number of professionals from both Amoco and academia have accompanied me in the field and lent their insights and assistance.

The first of these was Kenneth W. Ciriacks who as-



Text-figure 1.—Localities in Florida Bay sampled by this study.

sisted me in the first field work beginning in 1964 and also initiated me into the mysteries of clams and snails.

Brian F. Glenister, of the University of Iowa, was my associate on many of the later field trips and Amoco-sponsored seminars. In addition, he has arranged to house all of the study's collections at the Department of Geoscience at Iowa under the care of Julia Golden, the curator of the departmental collections. Several of his students also aided me in the field or laboratory.

Without the understanding support of Michael Waller, Director of the Amoco Research Center in Tulsa, both before and after my retirement, this study could never have been completed.

The contributions of Drs. Daniel, Kemp and Tabb have been mentioned in the text.

It was my practice when running seminars to invite observers from outside Amoco to whom the participants could turn for opinions other than my own and to act as a check on my enthusiasm. The late Conrad Gebelein, Rand Harrison, Gene Hinman, Harry Kent and Léo LaPorte all contributed in this way. Bob Ginsburg, in addition to his original impetus, was also an observer.

Many Amoco people contributed to this project by assisting in the field, by lecturing and by serving as instructors both ashore and in the Bay. Jeff Arbogast, Robert Duschatko, Peggy Gilbert, John Hughes, Alan Kendall, Susan Landon, A. Garrett Minke, Hugh Mitchell-Tapping, Edward Pittman, Jennifer Person, Gary Powers, Richard Schneider, Robert Scott, George Verville, Larry Vredenburgh and H. Dale Winland all have my thanks for their help.

Of the Amoco personnel who assisted in the field, in the laboratory and in the seminars, my special appreciation goes to George Ecker and Paul and Gale Ressmeyer. All three made contributions that were critical to the success of this work and of the seminars that were part of it.

Others contributed logistical support that was critical to the success of both the seminars and field work. Mahlon Ball lent us equipment and suggested valuable ways to improve our field work. Buck Hogle, long the Bell Captain at the Royal Biscayne Hotel, was ever solicitous of us and our comforts. Several local captains served as commodores for our seminar flotillas and guided us to unfrequented parts of the Bay to gather samples. Herb Alley was the first among them. He taught me how to find the obscure passes that thread the banks that block all direct routes through the Bay, and he shared with everyone his love of the bird life there. Steve Cole, with Don Washington, arranged our boats and cared for the equipment we left in the Keys between trips. Joe Enie, Harry Grigsby and Art "Graybeard" Hallander looked after us many times. Iowa students Shirley Sixt and Elise Zylstra also provided logistical support.

Many people in Amoco's Tulsa Research Center helped this project. First among these was Jack Richardson, who took a personal interest in all aspects of the investigation and preserved the samples and records during the fourteen years that I was not stationed in Tulsa. The survival of the collections that form the heart of this study is largely due to his care.

The records of the study were almost the first files of their size put into Amoco's computers. The Computing Group rose to the occasion by adapting an early hexadecimal program to the filing of Florida data. James Steward, James Tyler and Vince Jenneman were instrumental in getting the file operational. Harvey Meyer conducted factor analyses at a time when computer time was at a premium.

William Adams saved the project when there was opposition to the use of computers for filing data rather than for computation alone. He heard my reasons for conducting the study and the need for large data files to support it and ruled that the project would continue.

In later years, after the use of the data bank had been accepted, Robert Austin, Gary Beshara, Marilyn Tinsley and Jana Walker all assisted in managing the files and adapting them to the questions I needed to ask. Lynda Dalrymple, Sharon Davidson, René De Leon and Harley Goodwin developed workable procedures for data submission. Richard Hedlund for years saw to it that the data and taxonomic needs of the project received full and prompt attention.

Three of Brian Glenister's students, Juli Cook, Bruce Fouke and Elise Zylstra, picked many samples for me while working as summer employees.

Documentation of the taxa involved thousands of photographs and the creation of several hundred plates. Almost all of the technicians who helped me took part in this work at one time or another, but Tray Bartlett, Chris Criner, Ray Kozicki, Sharon Nelson and Heidi Williams devoted all or a large part of their time to this work.

In producing this published version, I am grateful for comments from Brian Glenister and William Lyons on previous drafts, and to Warren Allmon and his staff at the Paleontological Research Institution for their editorial efforts.

In addition to those mentioned here there are almost certainly others whose names have slipped my increasingly porous mind. To them I offer my apologies and the same gratitude I owe to those whose names I have remembered.

METHODS

Field Procedures

In shallow water we dug our samples with a shovel from the top four to six inches (15.2 cm) of the bottom sediments. After lithifaction this would probably create a bed of limestone no more than two to three inches (7.6 cm) thick. In water deeper than five feet (1.5 m), we used a simple pipe dredge. We also made sediment cores ranging from one to 13 feet (4 m) long and one to four inches (2.5–10 cm) in diameter.

After recovering a shovel sample we first measured its volume, then washed it through ordinary window screen with rectangular 0.10 by 0.13 mm openings. This reduced the amount of fine mud, lessening the weight and volume for shipping. Initially, we brought some unwashed samples to the laboratory and sieved them under controlled conditions to see if window screening was losing any significant part of the fauna. We found some loss of the smaller Foraminifera, but we were not studying them. Gastropod protoconchs that passed through the screen were generally too small to survive commonly into the fossil record and also generally too small for us to associate with adult shells and, thus, did not warrant our further attention. All molluscan shells large enough to be useful were retained on the window screen.

We shipped cores shorter than four feet (1.2 m) long to the laboratory intact. Longer ones were cut in the field. Uniformly muddy cores were cut into equal segments, usually 10 or 20 cm long. In cores showing natural lithological breaks we split our samples at those breaks.

At many locations we also took a supplemental sample of unwashed surface sediment. These gave us information on the percentage of mud in the sediment. We followed R.N. Ginsburg (pers. comm.), who defined "mud" as the fraction smaller than one-eighth mm.

We measured surface salinity in the field and collected a considerable number of water samples for laboratory analysis. In 1984–5 we made a quarterly salinity sampling over the entire Bay to determine annual patterns of change.

Finally, we submitted peat samples from cores for carbon-14 age dating.

Laboratory Procedures

PREPARATION: Shovel and dredge samples received in the laboratory were washed to remove whatever "mud" remained, then dried and stored until needed for study. Core samples normally remained in their core tubes until needed unless they had been cut in the field, in which case they received the same handling as the shovel and dredge samples.

It was obvious from the outset that it would be impossible to count all of the specimens in every sample. Some samples from the northern parts of Florida Bay contain many thousands of shells of a limited variety.

Table 1.—Summary of sampling.

SAMPLE TYPE	SAMPLES STUDIED	SPECIMENS COUNTED
SURFACE	190	393,080
CORE	99	133,446
NON-QUANTITATIVE	32	20,964
TOTALS	321	547,490

Counting such samples completely would have used up much valuable time without adding significantly to our knowledge of the fauna. Therefore, after some experimentation we developed an empirical routine of sieving through standard Tyler screens that divided samples to four manageable segments.

The first screen (No. 4 = 4.76 mm opening) captured the largest, and normally the least numerous, shells. The second screen (No. 6 = 3.36 mm), separated smaller shells but allowed most micromollusks to pass through. The third screen (No. 40 = 0.425 mm) normally contained the largest number and variety of shells. The 40-mesh screen allowed the residual fine sediment and the many tiny unidentifiable shells to pass through into the pan.

The 4-, 6- and 40-mesh subsamples came to be called Fractions 1, 2 and 3, respectively, and all counted specimens and unworked portions are labeled with the appropriate number. Pan residues are labeled "<40 mesh". I looked at more than half of the <40 mesh residues to be sure that they did not contain material that would have added significantly to the study; none did.

Table 1 summarizes the sampling on which this study is based.

Text-figure 1 indicates the general location of the quantitative samples we studied. Approximately 100 additional samples remain uncounted for lack of time, although we scanned most of them to see if they were likely to provide unanticipated data. All samples and records have been deposited with the Geoscience Department at the University of Iowa.

COUNTING: Fraction 1 (No. 4 mesh) included the largest and most visible specimens in each sample but, as noted above, they were not usually numerous. We counted all of these shells, except in unusually prolific samples. Fraction 2 normally contained a limited number of specimens but more than Fraction 1. In most samples both Fractions 1 and 2 were fully counted and the counts combined. In a few samples Fraction 2 was too large to allow complete counting and was kept separate. We separated Fraction 2 from Fraction 3 primarily because its larger shells hid many of the smaller shells in Fraction 3 and greatly slowed the counting.

While it was generally feasible to count all shells in Fraction 1 and often also in Fraction 2, it was usually impossible to make a complete count of Fraction 3. In these samples we took aliquots. The aliquot was weighed and compared to the weight of the complete Fraction. From this comparison we estimated the number of specimens in the whole Fraction.

Samples differed widely in their original volume and the Fractions also differed widely in weight, making it meaningless to use the raw counts of shells alone. At first we standardized our samples to the eight-quart (7.6 liter) volume that Turney (*in* Turney and Perkins, 1972) had used. Later we found a ten-quart (9.5 liter) standard volume easier to manipulate arithmetically, but, unfortunately, when samples containing the most abundant specimens were normalized to ten quarts the resulting numbers became so large that the computer software at the time could not handle them correctly. To avoid this problem we settled on a normalized volume of two liters, which was both closer to the actual volume of many of our samples and did not exceed the capacity of the computers.

In samples large enough to require aliquots, the aliquots frequently did not capture all of the scarcer taxa. To compensate for this we examined the unworked remainder of Fraction 3 and picked out individual specimens of any missing taxa. This gave us needed geographic information on the distribution of rare taxa without significantly biasing our counts because single specimens of this sort normally represented a proportion of less than 1:10,000. The choice of a normalized volume of two liters instead of one liter was deliberate to assure that the specimens of Fraction 10 would be too rare to add significant bias to our data. Specimens selected in this way are labeled as "Fraction 10" in the collections. The designation "10" arose while we were still standardizing our volumes to ten quarts.

NOMENCLATURE AND TAXONOMY

To have tried to find the "correct" name for each of the more than 300 mollusks we used would have imposed unacceptable delays on our seminars. For that reason we made no reference to "species" in our work but used the neutral word *taxon*. A taxon is herein simply a recognizable shell regardless of its formal nomenclature. Our working procedure was to set aside a few of the best-preserved specimens of each taxon for reference. For each, we set up a "taxon folder" containing photographs, written documentation of what was included in the taxon and, most usefully, a brief list of the characteristics by which the taxon could be discriminated from other taxa.

Each taxon received an acquisition number with which it could be entered into Amoco's computerized Paleontology File. If we ultimately found what seemed

to be an applicable formal name, we added it to the documentation, but the use of the Amoco numbers allowed us to avoid getting bogged down in formal nomenclature. At the end of the study only 17 of 336 taxa remained without a formal name.

An opposite sort of problem exists among a few of the common taxa. Rather than being unable to find a formal name, some of the taxa have too many names. Examination of hundreds or thousands of some of the common shells made it clear that multiple names have been coined for variants that either formed continuous morphologic series or were related to their habit of growth. A few "species" also appear to have been based upon specimens of different age. Such differences do not make a realistic basis for discrimination. Treating separately named taxa of this sort under one name causes some well known names to disappear. Where these taxa are mentioned in this report all of the suppressed names are cited at least once.

Discriminating the Biofacies

There are two contrasting approaches to the use of organisms in discriminating biologic assemblages. One is to use the dominant form(s) in each biota. The other is to choose those taxa that are unique to each biota.

Unfortunately for the latter approach, in Florida Bay the taxa that are unique to single biofacies are all too rare for credible use even in the laboratory, let alone in the field. All told, we identified 336 taxa from our surface samples. Of these, seven are fragile nonmarine taxa rarely well enough preserved to be separated in detail but critical in identifying some biofacies. The seven individual taxa are grouped here under three generic names: *Polygyra* (three taxa), *Truncatella* and *Gastrocopta* (two taxa each). This gave us 332 working taxa. In addition, we noted the presence of chiton plates, but we did not attempt to recognize individual taxa. Thirty eight of the 332 taxa appeared in a single biofacies. These 38 taxa were distributed among seven of the 14 biofacies as follows: *Cerithium* and Reef Tract Biofacies (9 taxa in each), Central Interior (7), Rocky Shore (6), Mud Flat and *Tricolia* (3 each) and Gulf (1 taxon). None of the remaining biofacies yielded unique taxa. This alone would negate the use of unique taxa as guides to biofacies. Furthermore, all of the 38 unique taxa are so uncommon that we cannot state with any statistical certainty that they do not exist in other biofacies. Clearly, specimens this rare are effectively useless for routine field sampling.

We thus had no real choice but to discriminate the biofacies on the evidence of the common taxa. These common taxa are of three sorts, which we call Dominant Taxa, Key Taxa and Ubiquitous Taxa. We used these common taxa to recognize 15 discrete biofacies (Table 2).

Table 2.—Recognized biofacies with abbreviations.

- Marine Biofacies
  - Northern Biofacies
    - *Parastarte* Subfacies (NO-P)
    - *Anomalocardia* Subfacies (NO-A)
  - Central Biofacies
    - Central Interior Biofacies (CI)
    - Central Exterior Biofacies (CX)
  - *Lucina* Biofacies (LU)
  - *Caecum* Group of Biofacies
    - *Cerithium* Biofacies (CE)
    - *Tricolia* Biofacies (TR)
    - Reef Tract Biofacies (RT)
  - Grecian Rocks Biofacies (GR)
  - Gulf Biofacies (GU)
- Quasimarine Biofacies
  - Everglades Biofacies (EV)
  - Mud Flat Biofacies (MF)
  - Playa Biofacies (PL)
  - Rocky Shore Biofacies (RS)
  - Beaches

Dominant taxa are the most numerous specimens in a sample. In most samples the first three to ten Dominant Taxa make up fifty percent or more of the total specimens recovered.

Key taxa are those of the Dominant Taxa that are critical in identifying a particular biofacies. A few taxa are Dominant in more than one biofacies and so do not by themselves discriminate a single biofacies. Key Taxa are both Dominant and distinctive of a biofacies.

Ubiquitous taxa are those few taxa that are Dominant in so many assemblages that they cannot be relied upon as Key Taxa. Ubiquitous Taxa are simply too widely developed to be useful and must be ignored in discriminating biofacies.

Faunal Structure

As noted above, Turney (*in* Turney and Perkins, 1972) estimated the abundance of the taxa he recognized and applied the numbers 1, 3, 6 and 10 to his four categories. When we began this study we also used his approach, but as we accumulated quantitative information we found that our counts did not confirm his basic concept. Many of his records cited more than one taxon as "abundant" or "common", but our counts showed that the faunas do not have that structure.

Instead, there is usually only one truly dominant taxon and few others that can even be called common.

As mentioned above, the first 50% of most samples is made up of only a few taxa—sometimes even a single taxon and usually five or less. In our 289 statistical samples only one had two equally dominant taxa. For this reason we did not finally incorporate Turney's estimates in our delineation of the biofacies, although we used most of his data in mapping taxon distributions.

Once it became apparent that all faunas show a strongly right-skewed structure I thought it might be possible to estimate the commonness at least of the most abundant taxa visually. If visual estimates could be refined, it would greatly lessen the time it took to bring the mollusks into use in our seminars. In several experiments I tried to estimate, before picking the samples, which of the taxa were the ten most common and their order of decreasing abundance. Even after more than 20 years of looking at samples and, being aware in advance which biofacies the sample probably represented, I was never able to place this many taxa in proper order. The first three to five taxa usually caused little trouble, but beyond that, my estimates were usually wrong. I also asked most of my trained assistants to make these estimates, with the same results.

Our inability to estimate relative abundances stems from the skewed structure of the assemblages. The counts of the less numerous taxa fall away sharply rather than in the gradual pattern of "normal" populations. By the time we try to estimate the order of abundance beyond the few most abundant taxa, the numbers have dropped off so far that all taxa appear to be almost equally rare.

There are two measures that clearly reflect the skewness of a fauna. The first is the number of taxa whose specimens are so abundant that, combined, they make up half of all the specimens. The second indicator of skewness is the number of taxa that are so rare that their total specimen count amounts to only 1% of all the specimens in the sample.

In a theoretically "normal" sample the most abundant item makes up 17% of the total specimens. In most Florida Bay samples the Dominant Taxon itself commonly makes up 40%, 50% or even more of the total. Also in a "normal" population the "tail" of the distribution (made up of the least common elements) contains 3.6% of the taxa. In Florida Bay molluscan samples the "tail" usually includes more than 40% of the taxa.

Table 3 lists these two numbers for 11 of the 14 biofacies described below. Table 3 is arranged, first, in order of the number of taxa forming the first 50% of the fauna and, second, in order of the percentage of the fauna in the last 1%. The Rocky Shore, Grecian Rocks and Playa assemblages are omitted because of insufficient sampling. The figures in Table 3 are averaged from all unambiguously identified samples. Transitional samples between biofacies are not included, although they are used in other contexts. Individual samples will, of course, depart in detail from these averages.

Table 3.—Biofacies structure.

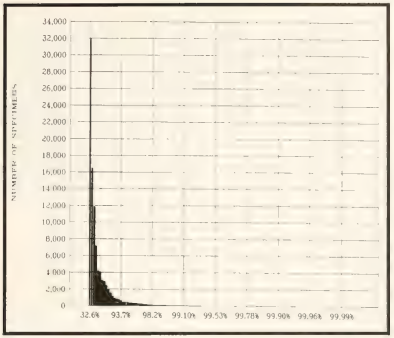
BIOFACIES	TOTAL TAXA	TAXA IN FIRST 50%	TAXA IN LAST 1%
EVERGLADES	52	2	33 (63.5%)
MUD FLAT	79	2	40 (56.6%)
NORTHERN *PARASTARTE*	130	3	86 (66.2%)
CENTRAL INTERIOR	215	4	138 (64.2%)
NORTHERN *ANOMALOCARDIA*	97	4	61 (62.9%)
LUCINA	127	4	66 (52.0%)
REEF TRACT	189	5	80 (42.3%)
GULF	178	5	73 (41.0%)
CENTRAL EXTERIOR	196	7	105 (53.7%)
CERITHIUM	248	10	100 (40.3%)
TRICOLIA	199	10	74 (37.2%)

Text-figures 2 and 3 are graphs of the Northern *Parastarte* Subfacies (left) and the *Tricolia* Biofacies (right). These are the most- and least-strongly skewed marine faunas summarized in Table 2. In the *Parastarte* Subfacies the first three taxa make up fully 50% of the taxa found, while the 86 least common taxa fall in the last 1% of the assemblage. In the *Tricolia* Biofacies, there are 10 taxa in the first 50% of the assemblage and only 74 in the last 1% although there are 69 more taxa in the *Tricolia* Biofacies than in the *Parastarte* Subfacies.

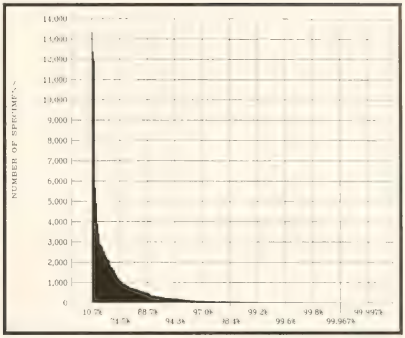
Another way of expressing this difference can be seen by comparing the scales on the two X-axes. In the *Parastarte* Subfacies the first vertical line on the left side of the graph (Text-fig. 2) represents 32.6% of the taxa and the fourth vertical grid line is at 99.1%. In the *Tricolia* Biofacies graph (Text-fig. 3) the left-hand grid represents only 10.7% of the taxa and the 99% level is reached only at the seventh vertical grid line.

The Biofacies

Dominance of each fauna by a few taxa is the characteristic that makes it possible to identify biofacies in



Text-figure 2.—Structure of Northern *Parastarte* Subfacies samples.



Text-figure 3.—Structure of *Tricolia* Biofacies samples.

the field. The skewed faunal structure makes it possible to identify a small number of Key Taxa to discriminate each biofacies. If the faunas were not so strongly skewed we would need to use many more taxa.

The marine molluscan biofacies defined below are based on analyses of surface samples. The same assemblages are present in the core samples, but we viewed core data as problems to be interpreted rather than part of our definitions. The only exception to this rule was the use of a single core sample in defining the quasimarine Everglades Biofacies. We did not go into The Everglades to sample this biofacies on the surface so most of our samples of it are from cores.

Our general order of presentation is similar to that used by Turney (*in* Turney and Perkins, 1972), starting in the north at The Everglades and moving outward toward the Gulf of Mexico on the west and toward the Atlantic reef tract to the east. The biofacies (with the abbreviations sometimes used in this report) are listed in Table 2.

Beaches are a special case. They develop in many places, but they are not a single biofacies. They show distinctive physically induced features, but the shells in them derive from the contiguous marine, quasimarine or nonmarine environments. The distinctive features of beach deposits are:

(1) a high proportion of comminuted shell fragments broken and abraded by wave action ("shell hash" or coquina);

(2) a low mud content;

(3) an unusually high proportion of smaller mollusks that have been carried in by storm flood water.

Aside from the overabundance of smaller shells, beaches also have an abnormal combination of marine forms with taxa that characterize playas or mud flats. A beach in northern Florida Bay will contain a Northern fauna mixed with nonmarine taxa typical of a mud flat. A beach in the southern Bay will show a mixture of shells from the *Tricolia* or *Cerithium* Biofacies with characteristic playa shells. Both will show the physically abraded shell fragments and the high proportion of small shells, but the shells will be of different taxa.

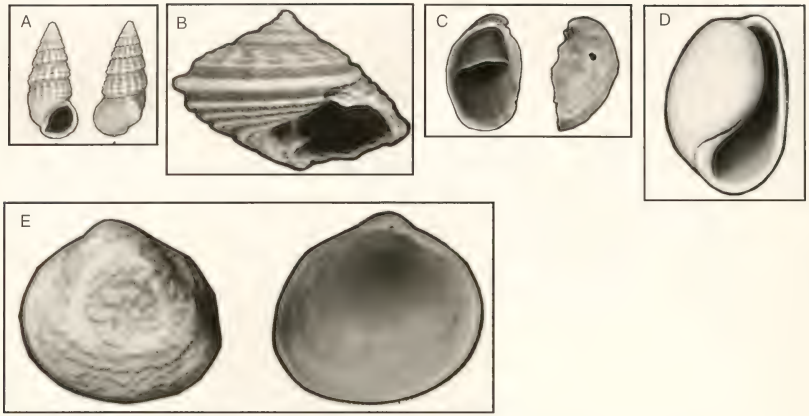
Large fragile shells are uncommon on beaches because they are usually broken up by the same water movements that creates the beach. Larger heavy shells are not commonly present because wave action of less than hurricane intensity is not competent to bring them onto the beach.

THE UBIQUITOUS TAXA

Before we discuss the remaining biofacies we need to digress and consider those forms that we have chosen to call the "Ubiquitous Taxa". These are taxa so common in so many places that they are not distinctive of any biofacies. It must be stressed, too, that these shells are often found among the most common forms in many samples; hence they are commonly Dominant Taxa, but they are not Key Taxa.

Five taxa qualify for inclusion here (Table 4; Text-fig. 4). All have been found in a majority of the 190 quantitative surface samples, and all are present in either 8 or 9 of the marine biofacies. The count of nine marine biofacies excludes the Quasimarine Biofacies and treats the Northern Biofacies as one because all of the Ubiquitous Taxa are present in both subfacies.

All of the Ubiquitous Taxa also appear as Dominant Taxa in some samples but not equally often. In this



Text-figure 4.—The Ubiquitous Taxa. A. *Diastoma varia*. B. *Modulus modulus*. C. *Crepidula fornicata*. D. *Bulla striata*. E. *Laevicardium laevigatum*.

regard, *Diastoma varia* (Text-fig. 4A) is by all measures the winner. It is most abundant in the Playa Biofacies, to be discussed later, where it is washed ashore by storms in great numbers. It is most common in the marine Central Exterior Biofacies, averaging 10.6% in our samples.

Modulus modulus (Text-fig. 4B, p. 57) (as defined in Appendix 1) is widely abundant. It, like *Diastoma*, is present in all marine biofacies, but it is less commonly the Dominant Taxon. It is most common in the *Cerithium* Biofacies (4.1% of our samples), but it appears to thrive in all areas of agitated water, such as along the southern edge of the western mudbanks and other places exposed to greater wave action.

The three remaining Ubiquitous Taxa have been found in all marine biofacies except the poorly known Grecian Rocks assemblage.

The immobile snail *Crepidula* (Text-fig. 4C) (see Appendix 1, p. 60, for comments on nomenclature and habits) is the most widely distributed mollusk. It was found in 175 of the 190 quantitative surface samples, and it was one of the three most numerous Dominant Taxa in more samples than any taxon except *Diastoma*.

Bulla (Text-fig. 4D) is almost as widely developed

Table 4.—The Ubiquitous Taxa.

Taxa	In how many samples out of 190 studied?	dominant in how many samples?	present in how many of nine marine biofacies?
Crepidula	175	31	8
Modulus	172	15	9
Bulla	171	8	8
Laevicardium	169	10	8
Diastoma	162	40	9

as *Diastoma* and *Crepidula,* appearing in 171 of 190 surface samples, but it is much less commonly a Dominant Taxon than any of the others. It is most abundant in the *Lucina* Biofacies at 2.6%.

The only clam that is present widely enough to be included in the Ubiquitous group is *Laevicardium laevigatum* (Text-fig. 4E). Like *Bulla,* it is widespread but not commonly a Dominant Taxon.

The small snail *Batillaria minima* (Text-fig. 50A, B) is a special case. It is abundantly present in a number of biofacies, but it is never a Key Taxon. It appears in enormous numbers in bands up to about 25 yards (23 m) wide around some keys, but it is rare elsewhere. The upper surfaces of some of the mud banks in the more restricted parts of Florida Bay are strewn with great numbers of dead *Batillaria,* mute testimony to the former presence of now-vanished keys. It conveys this message about the environment everywhere it is found in large numbers regardless of the surrounding biofacies.

A Caveat about the Maps

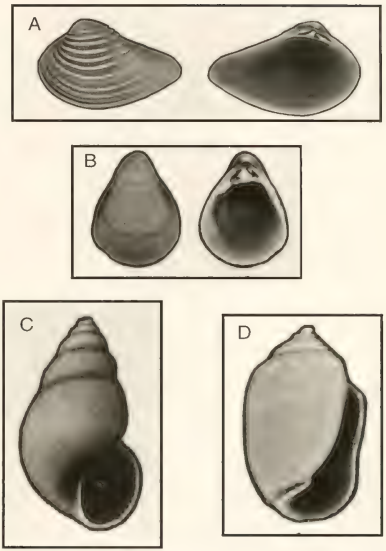
The reader should keep in mind that the biofacies maps presented here are only first approximations. Text-figure 1 shows that sampling was distributed fairly evenly, but it does not give an adequate impression of how far apart those shovel, dredge and core samples really are. The area of Florida Bay that we studied is very close to 800 square miles (1287.2 km^2). From this vast expanse we examined 190 samples quantitatively, an average of less than one sample for every four square miles (6.4 km^2). Obviously, the resulting maps are very much generalized.

An example will make it clearer how little we yet know of the true boundaries of these biofacies. On May 23, 1966, we stopped in the channel between Windley and Upper Matecumbe Keys (Whale Harbor). As an experiment we dredged a sample from the bottom of the channel over the stern of our boat. Then we dug a shovel sample from the mud bank at the bow of the boat. The channel proved to have a *Tricolia* fauna, while the bank, just a boat's length away, yielded a Central Exterior fauna. It seems inevitable that more closely-spaced sampling almost anywhere in the Bay will yield much more complex patterns than our maps show.

THE MARINE BIOFACIES

Northern Biofacies

KEY TAXA: The Northern Biofacies is dominated by either of two clams: *Anomalocardia auberiana* or the tiny *Parastarte triquetra* (Text-fig. 5A, B). Analysis of all occurrences of both shells where we recorded water depth shows that *Parastarte* is most abundant in water about 21 inches (53 cm) deep while *Anomalocardia* is more abundant in water about 42 inches (ca. 107 cm) deep.

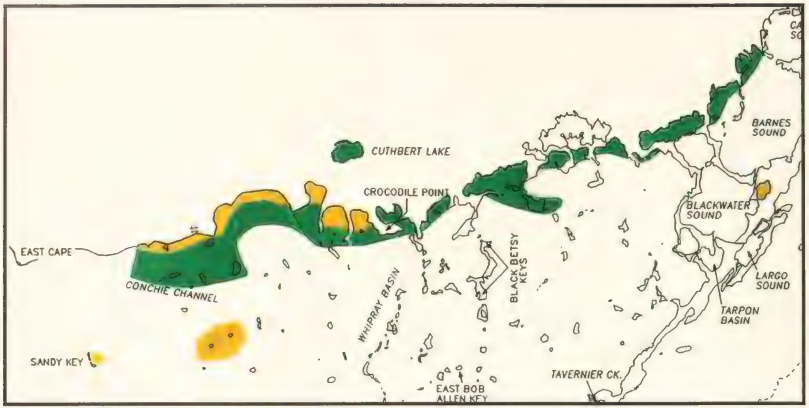


Text-figure 5.—Most important taxa of the Northern Biofacies. A. *Anomalocardia auberiana.* B. *Parastarte triquetra.* C. *Hydrobia totteni.* D. *Retusa candei.*

The preference of *Parastarte* for shallower water makes it the more commonly Dominant Taxon in the western half of the Northern area which is generally filled with mud (Text-fig. 6). East of the Black Betsy Keys the "lakes" have less mud filling so the water is slightly deeper and *Anomalocardia* dominates.

In the shallower *Parastarte* subfacies *Parastarte* (32.6%) and *Anomalocardia* (16.8%) together make up 49.4% of all mollusks. In the *Anomalocardia* subfacies *Anomalocardia* dominates (22.4%), but *Parastarte* becomes a minor element (1.2%).

The *Parastarte* and *Anomalocardia* assemblages are treated as subfacies because of the importance of *Anomalocardia* in both. The shift upward from the *Anomalocardia* into the *Parastarte* assemblage that reflects a gradual shallowing can be seen in cores from the western bights along the northern edge of Florida



Text-figure 6.—Map of the Northern Biofacies: yellow shading depicts *Parastarte* subfacies; green shading depicts *Anomalocardia* subfacies.

Bay. This application is described later (Text-figs. 34–36).

In the *Anomalocardia* subfacies the second and third most common taxa are the washed-in nonmarine snail *Hydrobia totteni*, and the minute marine snail *Retusa candei* (Text-fig. 5C, D). These three taxa combine to make up the first 49.9% of all shells. In the *Parastarte* subfacies *Parastarte* and *Anomalocardia* alone total 49.4% of the fauna.

DISTRIBUTION: The two subfacies extend along the inlets, lakes and bights that border The Everglades westward from the high bridge at Card Sound to a point just west of Flamingo (Text-fig. 6). Where the water is shallowest, the *Parastarte* subfauna appears; elsewhere *Anomalocardia* dominates. Isolated outliers of the *Parastarte* subfacies are also present where the mud banks are shallow enough around Johnson Key, behind Sandy Key and in Lake Surprise on Key Largo.

The Central Biofacies

The next two biofacies characterize most of Florida Bay, and because they are much alike they are grouped under the title "Central". They roughly correspond to the area called "Central" by Turney (*in* Turney and Perkins, 1972).

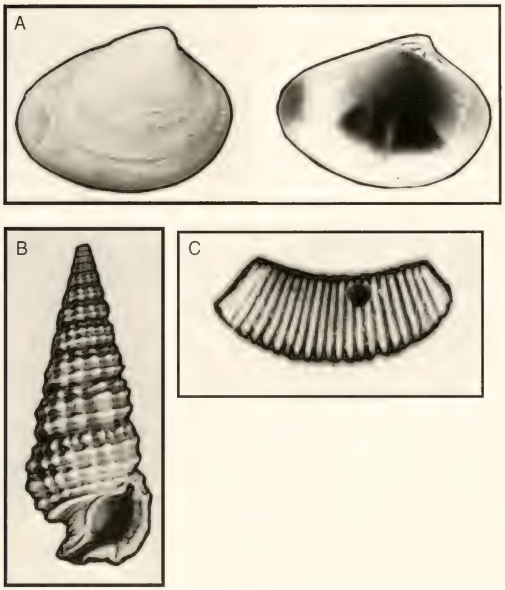
Central Interior Biofacies

DOMINANT TAXA: *Transennella conradina* (36.1%) (Text-fig. 7A), *Brachidontes exustus* (7.4%) (Text-fig. 8A) and *Cerithium muscarum* (5.0%) (Text-fig. 7B). The minute mollusk *Caecum pulchellum* is common (5.4%) (Text-fig. 7C) and is useful in the lab but it is too small for field use. The omnipresent *Diastoma varia* (Text-fig. 4A) is present at 5.1%

KEY TAXA: Samples in which *T. conradina* (Text-fig. 7A) (as defined in Appendix 1, p. 62) is the Dominant Taxon can be assigned to the Central Interior Biofacies. The specific percentages given above will, of course, not be present in every Central Interior sample, but *T. conradina* must be more abundant than *B. exustus* for a sample to be classified as Central Interior. Samples in which *B. exustus* dominates belong to the Central Exterior Biofacies.

The relative importance of the three major taxa, *T. conradina*, *B. exustus* and *C. muscarum*, also varies within the Central Interior area. Near the northern edge of the biofacies, some samples have the three major taxa making up over 80% of the whole, while at the outer edge of the area the percentage drops to 32–45%. The definitive feature is the dominance of *T. conradina*.

TRANSITION FROM THE NORTHERN BIOFACIES: The transitional nature of all "boundaries" between biofacies needs emphasis. Faunas from the central part of any biofacies are normally easy to assign, but as we approach a neighboring biofacies, the faunas gradually shift from one biofacies toward the next.



Text-figure 7.—Most important taxa of the Central Interior Biofacies. A. *Transennella conradina*. B. *Cerithium muscarum*. C. *Caecum pulchellum*.

There is never a dramatic, wholesale shift from one set of taxa to another.

The Central Interior fauna changes from the Northern fauna primarily by addition of new taxa. The Northern Biofacies includes 142 taxa in both subfacies, and 137 of these are also present in the Central Interior Biofacies. Thus, only five taxa drop out in the transition. On the other hand, there are 73 taxa in the Central Interior Biofacies that are not found in either Northern Subfacies. So although 96.5% of the Northern taxa carry over into the Central Interior, 34% of the Central Interior taxa (73 of 215) are new.

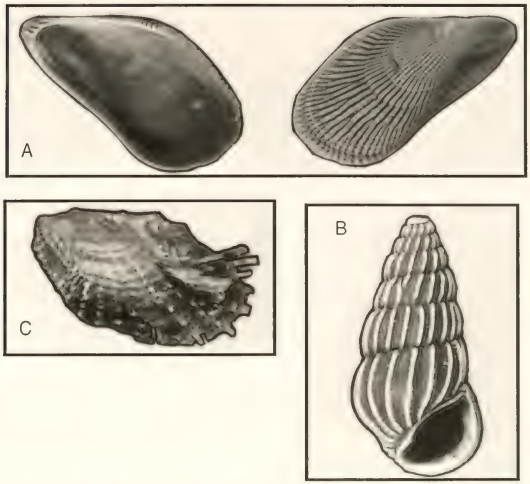
BIOFACIES STRUCTURE: We have found 215 taxa in typical samples of the Central Interior Biofacies (Table 3), but 138 taxa (64.2%) are present in such small numbers that in aggregate they make up only the final 1% of the normalized specimen count. Obviously, these minor elements are rare or absent in most field samples.

Central Exterior Biofacies

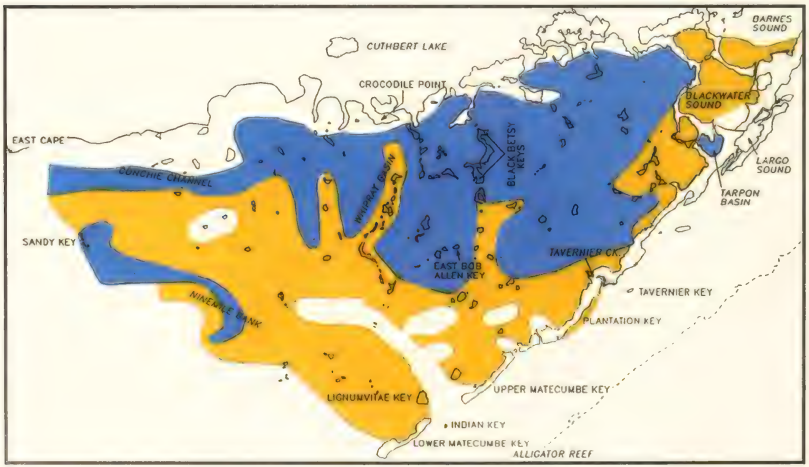
DOMINANT TAXA: Many of the Dominants in this biofacies are Ubiquitous Taxa. These include *Diastoma*, *Crepidula*, and *Laevicardium* (Text-figs. 4A, C, E, respectively).

KEY TAXA are *Brachidontes exustus* (17.6%) (Text-fig. 8A), *Rissoina bryerea* (5.6%) (Text-fig. 8B), *Caecum pulchellum* (5.3%) (Text-fig. 7C), and *Pinctada imbricata* (2.6%) (Text-fig. 8C). *B. exustus* is the critical taxon. If it is the Dominant non-Ubiquitous Taxon then the biofacies can be identified confidently as Central Exterior.

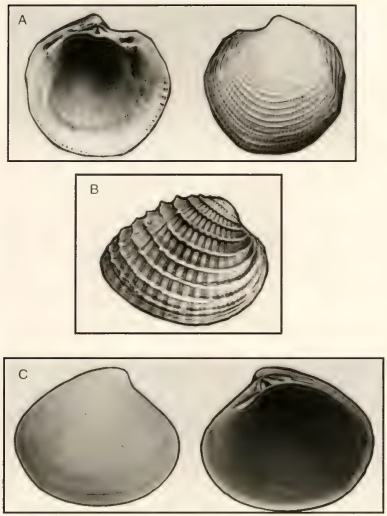
DISTRIBUTION: As their names indicate, the two Central Biofacies dominate most of central Florida Bay (Text-fig. 9). One notable feature of Text-figure 9 is the invasion of tongues of the Central Exterior Biofacies into the Interior fauna along shallow banks and chains of keys. The shallowing allows *B. exustus* to



Text-figure 8.—Most important taxa of the Central Exterior Biofacies. A. *Brachidontes exustus*. B. *Rissoina bryerea*. C. *Pinctada imbricata*.



Text-figure 9.—Map of the Central Biofacies: yellow shading depicts Exterior Biofacies; blue shading depicts Interior Biofacies.



Text-figure 10.—Most important taxa of the *Lucina* Biofacies. A. *Parvilucina multineata*. B. *Chione cancellata*. C. *Transennella stumpsoni*.

find the water depths that it prefers even though the adjacent areas of deeper water are still dominated by *Transennella conradina* (Text-fig. 7A). Although the development of Central Exterior faunas on these banks could suggest a depth-sensitive relation similar to that of the two Northern subfacies, the two Central Biofacies are sufficiently different to warrant separation. Whereas the two Northern subfacies are composed of the same basic taxonomic elements only differing in relative amounts, the two Central Biofacies show significant differences in their total faunas.

TRANSITION BETWEEN THE TWO CENTRAL BIOFACIES: Samples taken near the boundary between the two Central Biofacies can yield nearly equal numbers of *T. conradina* and *B. exustus* because one of them is increasing in number while the other declines. The fact that *B. exustus* is the second most common form in the Central Interior assemblage could suggest that the two Central faunas differ very little. But a dramatic drop in the abundance of *T. conradina* from its number-one position in the Central Interior to thirteenth place in the Central Exterior makes discrimination easy.

Table 5.—Percentages of the most abundant taxa in the Central Interior (CI), Central Exterior (CX) and *Lucina* (LU) Biofacies.

TAXA	CI	CX	LU
Transennella conradina	36.1	1.7	3.1
Brachidontes exustus	7.4	19.1	4.1
Parvilucina multilineata	0.3	1.2	29.1
Cerithium muscarum	5.0	3.2	0.6
Laevicardium laevigatum	4.7	3.9	7.6
Caecum pulchellum	5.4	7.8	5.2
Crepidula fornicata	4.3	3.7	0.9
Transennella stimpsoni	3.0	3.2	9.6
Rissoina bryerea	1.9	7.0	3.8
Pinctada imbricata	0.8	3.8	2.1
Chione cancellata	1.9	3.8	5.2

Of the remaining taxa listed above *Pinctada* is the most helpful. Although it is actually rare, its shell is so fragile that it breaks up easily, creating myriad shiny flakes that betray its presence. *Laevicardium* is also a minor element of many Central Interior and Northern samples, but it is not definitive.

Lucina Biofacies

DOMINANT TAXA: *Parvilucina multilineata* (29.1%), *Chione cancellata* and *Transennella stimpsoni* (5.2%) (Text-fig. 10A–C).

KEY TAXA: Where *P. multilineata* is Dominant, it is sufficient by itself to identify this biofacies. The other taxa are also present in other biofacies.

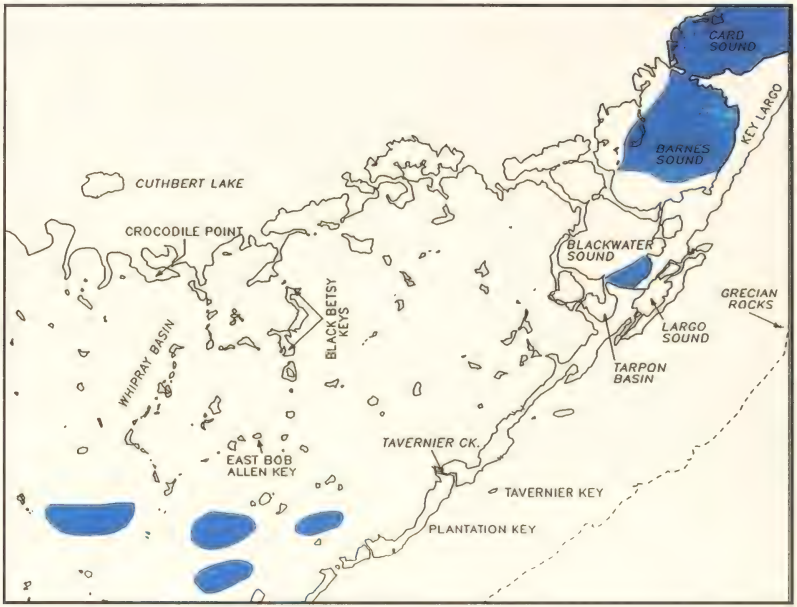
FAUNAL STRUCTURE: Table 5 shows how strongly the Key Taxa dominate typical samples from the *Lucina* and the two Central Biofacies. In each, the second most abundant form is less than half as common as the first. The *Lucina* fauna is somewhat less strongly skewed than others in Florida Bay. Of its 127 taxa, 66 (52.0%) are found in the last one percent.

DISTRIBUTION: The *Lucina* Biofacies appears in four small "lakes" bordering the Central Exterior Biofacies in the southern part of the Bay (Text-fig. 11). It is also the principal fauna in Card and Barnes Sounds in the northeastern corner of the study area. Its presence there suggests that Biscayne Bay to the north might exhibit significant faunal differences from those seen in Florida Bay, but we did not pursue that question.

Parvilucina multilineata itself appears to develop most abundantly in waters slightly deeper than *Brachidontes exustus*, the Key Taxon of the Central Exterior Biofacies. These relations are discussed below in connection with Text-figures 27 and 28.

The *Caecum* Group of Biofacies

The next three Biofacies are similar in that various minute snails assigned to *Caecum* are among the Dom-



Text-figure 11.—Map of the *Lucina* Biofacies (blue shading).

inant Taxa in each. However, the small size of caecids makes them unsatisfactory for field use so we emphasize the larger shells in the following diagnoses. The percentages of *Caecum* are noted, but other Key Taxa are chosen for field use.

Cerithium Biofacies

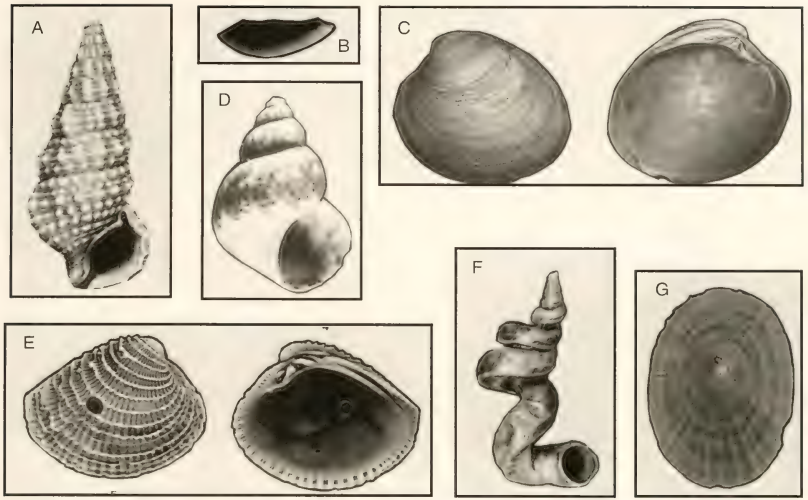
With the *Cerithium* Biofacies we leave the more restricted, muddier parts of Florida Bay and move outward into the areas where water motion is more active and sediments are, as a result, coarser-grained. These waters also show less dramatic swings in salinity (Text-fig. 13).

DOMINANT TAXA: The *Cerithium* assemblage is the second most varied in the Bay, containing 248 taxa, of which the following ten comprise the first half of the fauna: *Cerithium atratum* (13.1%) (Text-fig. 12A), *Caecum nitidum* (7.6%) (Text-fig. 12B), *Mercenaria mercenaria* (5.7%) (Text-fig. 12C), *Tricolia affinis* (5.3%) (Text-fig. 12D), *Chione intapurpurea* (5.3%) (Text-fig. 12E), *Vermicularia spirata* (4.2%) (Text-fig. 12F), *Modulus modulus* (4.1%), *Bulla striata* (2.1%), *Transennella stimpsoni* (1.7%), and *Acmaea antillarum* (1.6%) (Text-fig. 12G). The tiny opercula of *Tricolia* (Text-fig. 53H) make up 1.2% of the fauna.

KEY TAXA: *Bulla* and *Modulus* can be ignored, along with *Caecum nitidum* so that the usable field taxa become *Cerithium atratum, Mercenaria, Tricolia, Vermicularia, Chione intapurpurea, Transennella stimpsoni* and *Acmaea.* This is a distinctive group of taxa.

BIOFACIES STRUCTURE: Like all of the biofacies, this is right-skewed (Table 3) although not so strongly as some others. Of the 248 taxa found in typical *Cerithium* samples, the ten listed taxa make up half of the fauna while there are 100 taxa in the rarest 1%. The remaining 138 taxa comprise the intervening 49%.

DISTRIBUTION: The *Cerithium* Biofacies develops in the more open-water areas of the southwestern



Text-figure 12.—Most important taxa of the *Cerithium* Biofacies. A. *Cerithium atratum*. B. *Caecum nitidum*. C. *Mercenaria mercenaria*. D. *Tricolia affinis*. E. *Chione intapurpurea*. F. *Vermicularia spirata*. G. *Acmaea antillarum*.

Bay (Text-fig. 13), lying mainly opposite the gaps between the keys southwest of Lower Matecumbe Key. Smaller patches also lie opposite the gap between the two Matecumbe Keys and between Plantation Key and Key Largo. North of Plantation Key there is a widening band of the biofacies that borders the Atlantic side of the rock keys as far as we carried our sampling.

The *Cerithium* fauna appears to form a sort of buffer zone between the *Tricolia* Biofacies and the more restricted Central faunas, and it could be that more detailed sampling and mapping will show it more widespread in this position than is here documented.

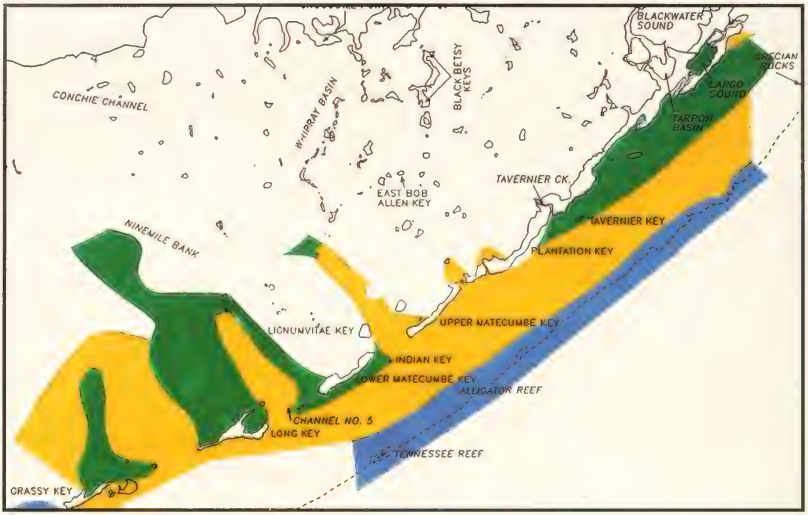
TRANSITION FROM THE CENTRAL EXTERIOR BIOFACIES: If we look only at the Dominant and Key Taxa, the shift from the Central Interior to the *Cerithium* Biofacies is much more abrupt than that between the Biofacies discussed earlier, but, viewed as a whole, the taxa of the two assemblages are largely the same. The 19 typical (non-transitional) samples from the *Cerithium* Biofacies contain 248 taxa. The 32 samples from the Central Exterior Biofacies contain 196 taxa. Only 16 Central Exterior taxa fail to reappear in the *Cerithium* assemblage, so 180 taxa are common to both biofacies; 68 taxa are new in the *Cerithium* fauna.

Tricolia Biofacies

DOMINANT TAXA: *Caecum nitidum* (10.7%) (Text-fig. 12B), *Tricolia affinis* (10.0%) (and its opercula, 3.9%) (Text-fig. 12D), *Caecum pulchellum* (9.6%) (Text-fig. 7C), *Finella dubia* (4.5%) (Text-fig. 14A), *Cerithium atratum* (3.1%) (Text-fig. 12A), *Ervilia concentrica* (2.3%) (Text-fig. 14B), *Vermicularia spirata* (2.3%) (Text-fig. 12F), *Chione intapurpurea* (2.2%) (Text-fig. 12E) and, inevitably, *Diastoma varia* (2.7%) (Text-fig. 4A).

KEY TAXA: The combination of the two species of *Caecum* is definitive of the *Tricolia* Biofacies in the laboratory. The *Caecum* spp. in the Reef Tract Biofacies, to be described next, are different. For field use, the Key Taxa are the small snail *Tricolia*, the uncoiled *Vermicularia* and the small clam *E. concentrica* against a background of many caecids. *Cerithium atratum* is still common but is no longer a Dominant.

DISTRIBUTION: The *Tricolia* Biofacies lies intermediate between the *Cerithium* and Reef Tract Biofacies (Text-fig. 13). In the southwestern Bay it appears to isolate an area of banks on which the *Cerithium* Biofacies has developed. From its widespread



Text-figure 13.—Map of the *Caecum* Group of Biofacies: yellow shading depicts *Tricolia* Biofacies; blue shading depicts Reef Tract Biofacies; green shading depicts *Cerithium* Biofacies.

development in the southwestern Bay *Tricolia* moves to a central position on the reef tract between the *Cerithium* and Reef Tract Biofacies.

TRANSITION FROM THE *CERITHIUM* BIOFACIES: The *Cerithium* and *Tricolia* biofacies are the largest in Florida Bay. The *Cerithium* Biofacies has 248 taxa, and the *Tricolia* Biofacies 255, with 220 in common. In the shift from *Cerithium* into *Tricolia*, 28 *Cerithium* Biofacies taxa drop out, and 35 appear, new to the *Tricolia* Biofacies. Both because of their large percentage of common taxa and because of their close geographic association, transitional samples between the *Cerithium* and *Tricolia* Biofacies are fairly common.

Reef Tract Biofacies

DOMINANT TAXA: *Caecum* truly dominates the fauna found on the outer part of the reef tract (Table 6). The four most common taxa are *Caecum cornucopiae* (17.3%) (Text-fig. 15A), *C. pulchellum* (14.4%) (Text-fig. 7C), *C. nitidum* (8.5%) (Text-fig. 12B), and *Pleuromeris tridentata* (5.9%) (Text-fig. 15B).

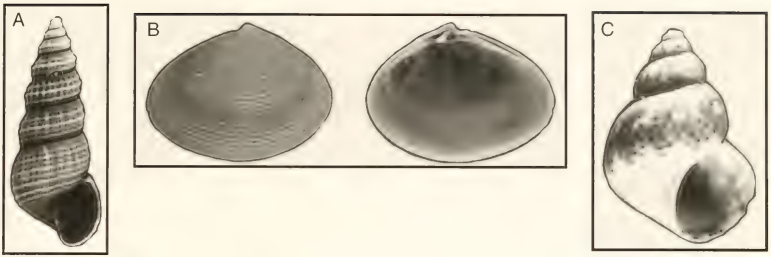
RECOGNITION OF THE BIOFACIES: This fauna is the only assemblage on the outer part of the reef tract, other than the incompletely known fauna at Grecian Rocks. It can be distinguished at two levels. A field sample containing 40% or more of caecids, regardless of the species, is part of the Reef Tract Biofacies. In the laboratory, the critical clue is the abrupt increase in numbers of *C. cornucopiae*. It is not important elsewhere.

SUBSIDIARY TAXA: A number of larger, but less common taxa are more numerous on the reef tract than in Florida Bay. There are new kinds of pelecypods (chamids and pectens) plus those large and spectacular gastropod shells so sought after by collectors, like *Strombus* and *Cassis*. *Transennella cubaniana* and *Chama florida* (Text-fig. 15C, D), shown here, are listed in Table 6. If they appear in your samples they are helpful, but they will not invariably be present.

FAUNAL STRUCTURE: The fauna is right skewed, with 80 (42.3%) of its 189 taxa in the last 1%.

Comparisons Among the *Caecum* Group Biofacies

Table 6 compares percentages of the Key and Dominant Taxa in the *Cerithium* (CE), *Tricolia* (TR) and



Text-figure 14.—Most important taxa of the *Tricolia* Biofacies. A. *Finella dubia*. B. *Ervilia concentrica*. C. *Tricolia affinis*.

Reef Tract (RT) Biofacies. It illustrates again how biofacies are separated by shifts in the proportions of a small number of taxa, most of which are present in several biofacies.

Grecian Rocks Biofacies

This biofacies is based on only two samples collected at Grecian Rocks. It appears to be sufficiently different from the Reef Tract Biofacies that borders it on the west to warrant separation, but with only two samples available it is not yet sufficiently understood for detailed analysis and comparisons.

DOMINANT TAXA: Eleven taxa make up the first 50% of the assemblage: *Caecum pulchellum* (9.2%) (Text-fig. 7C), *Rissoina fischeri* (7.0%) (Text-fig. 16A), *Barbatia domingensis* (5.7%) (Text-fig. 16B), *Tricolia affinis* (4.8%) (Text-fig. 14C), *Rissoina bryerea* (4.7%) (Text-fig. 8B), *Alvania auberiana* (4.2%) (Text-fig. 16C), *Finella dubia* (3.8%) (Text-fig. 14A), *Barbatia cancellaria* (3.7%) (Text-fig. 16D), *Marginella carnea* (3.5%) (Text-fig. 16E), *Cerithiopsis greenii* (3.0%) (Text-fig. 16F) and *Cerithium litteratum* (2.8%) (Text-fig. 16G).

Table 6.—Percentages of the most abundant taxa in the *Caecum* Group of biofacies. CE = *Cerithium* Biofacies; RT = Reef Tract Biofacies; TR = *Tricolia* Biofacies.

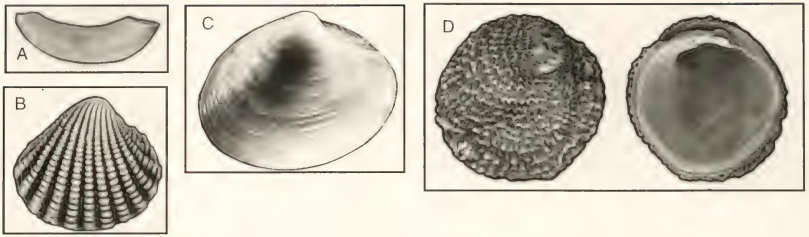
TAXA	CE	TR	RT
Cerithium atratum	13.1	3.1	0.2
Caecum nitidum	7.6	10.7	8.5
Caecum nebulosum	0.6	2.0	17.3
Caecum pulchellum	1.6	9.6	14.4
Tricolia	5.3	10.0	5.7
Tricolia opercula	1.2	3.9	3.4
Mercenaria mercenaria	5.7	1.9	1.3
Chione intapurpurea	5.3	2.2	1.3
Finella dubia	1.3	4.5	4.5
Vermicularia spirata	4.2	2.3	0.6
Transennella stimpsoni	1.7	1.7	0.02
Acmaea antillarum	1.6	0.8	0.3
Ervilia concentrica	1.0	2.3	1.8
Pleuromeris tridentata	0.1	2.0	5.9
Transennella cubaniana	0.05	0.1	4.5
Chama florida	0.03	0.07	1.6

KEY TAXA: As in the Reef Tract Biofacies, this fauna also starts out with a *Caecum*, but the other characteristic Reef Tract caecids are not part of the first 50% of this fauna. Only *Tricolia* carries over importantly from the Reef Tract Biofacies. The remainder of the taxa appear to be sufficiently unlike others seen on the outer reef tract to warrant separation, but the assemblage is still poorly known.

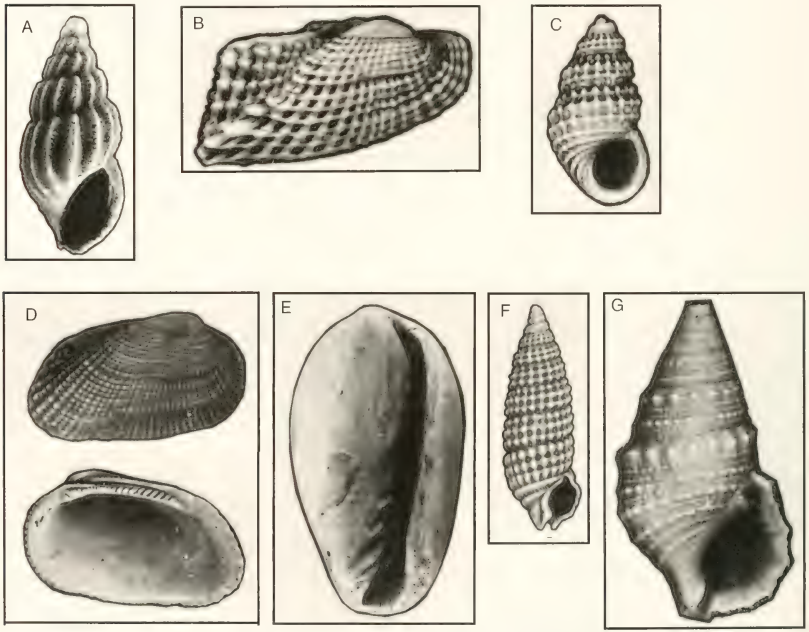
BIOFACIES STRUCTURE: The two Grecian Rocks samples are less strongly skewed than those from other biofacies. There are ten taxa in the first 50% of the specimens and only 16 of the 100 taxa in the fauna as now known are confined to the final one percent; this contrasts sharply with the 40% or more in the tails of other biofacies. Likewise the most common taxon, *Caecum pulchellum*, is less abundant than the main taxon in other biofacies. With further sampling I suspect that these anomalies will diminish, or even vanish entirely. It is too early to make rigorous comparisons with other faunas.

Gulf Biofacies

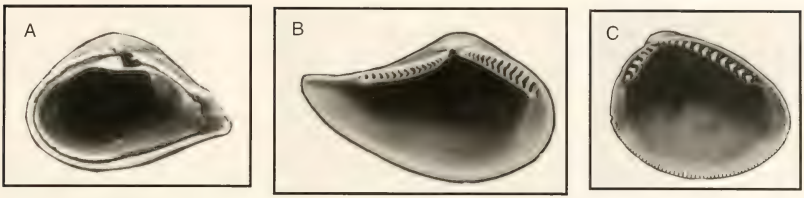
This assemblage, like that from Grecian Rocks, lies at the boundary of the study area and was not sampled in detail. We worked out to the edge of the banks that are characteristic of Florida Bay but not far beyond them, where water depth generally exceeds 10–12 feet (3.6 m). Here we find the "Western Florida" shelly fauna so widely known at places like Marco Island and described in many references. Our four typical samples yielded only 178 taxa, but many more taxa have been described elsewhere.



Text-figure 15.—Most important taxa of the Reef Tract Biofacies. A. *Caecum cornucopiae*. B. *Pleuromeris tridentata*. C. *Transennella cubaniana*. D. *Chama florida*



Text-figure 16.—Most important taxa of the Grecian Rock Biofacies. A. *Rissoina fischeri*. B. *Barbatia domingensis*. C. *Alvania auberiana*. D. *Barbatia cancellaria*. E. *Marginella carnea*. F. *Cerithiopsis greenii*. G. *Cerithium litteratum*.



Text-figure 17.—Most important taxa of the Gulf Biofacies. A. *Corbula swiftiana*. B. *Nuculana acuta*. C. *Nucula proxima*.

DOMINANT TAXA: Five taxa make up the first half of this fauna: *Corbula swiftiana* (13.5%) (Text-fig. 17A), *Chione cancellata* (12.5%) (Text-fig. 10B), *Transennella stimpsoni* (12.3%) (Text-fig. 10C), *Nucula proxima* (9.8%) (Text-fig. 17C) and *Nuculana acuta* (5.0%) (Text-fig. 17B).

KEY TAXA: *Chione cancellata* and *Transennella stimpsoni* occur in almost all parts of the Bay, but neither approaches the abundance seen in the Gulf Biofacies. The remaining taxa are more striking because they are uncommon elsewhere. A sample with numerous *Corbula, Nucula* and *Nuculana* can safely be identified with the Gulf Biofacies.

BIOFACIES STRUCTURE: The fact that only five taxa make up half of this assemblage is clear indication that this is also a right-skewed fauna. Of its 178 taxa, 73 (41.0%) fall in the final one percent.

DISTRIBUTION: As mentioned above, this fauna begins at the western edge of our Florida Bay study, where the mud banks and "lakes" disappear and the shelving ramp of the Gulf of Mexico begins (Text-fig. 18), A small embayment of it exists between Sprigger and Ninemile Banks where there are no banks to limit influx of Gulf waters.

Text-figure 18.—Map of the Gulf Biofacies.

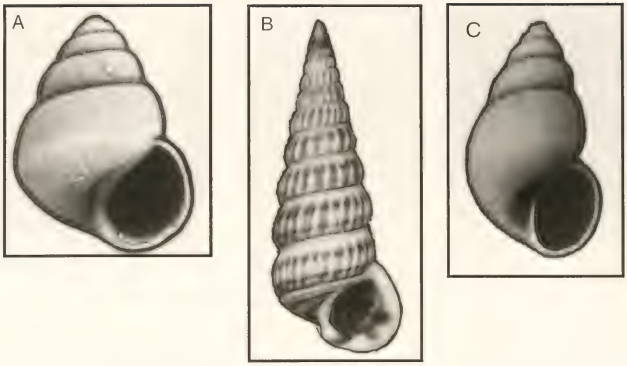
The Quasimarine Biofacies

Four more biofacies are recognizable. They contain specialized mollusks, adapted to living either on land or on land that is intermittently flooded by the sea. The Everglades Biofacies lies at the boundary between the freshwater Everglades and the marine Florida Bay. The Playa Biofacies develops on the shallow, frequently inundated, evaporitic flats that form the interior of many of the mud keys in the Bay. The Mud Flat Biofacies forms on flats, commonly the site of mangrove thickets, which develop on the rock keys and locally along the edge of the Everglades. Finally there is the Rocky Shore Biofacies found on rocky outcrops along the Atlantic side of the rock keys.

Everglades Biofacies

This biofacies reflects the freshwater effect of the Everglades. In its pure form it would consist entirely of terrestrial or freshwater shells. In samples from the northern edge of the Bay, however, there is normally an admixture of Northern Biofacies marine shells.

KEY TAXA: Two small nonmarine snail shells dominate Everglades samples. The first is *Hydrobia totteni* (33.0%) (Text-fig. 19C), and the other we know only by its Amoco designation, Gastropod 2482



Text-figure 19.—Most important taxa of the Everglades Biofacies. A. Gastropod 2482. B. *Cerithidea costata*. C. *Hydrobia totteni*.

(19.2%) (Text-fig. 19A). Both are trochoid shells 2–4 mm high. *Hydrobia* has an open umbilicus, while in Gastropod 2482 the umbilicus is covered by callus. These two shells together make up about 50% of a typical Everglades sample. *Cerithidea costata* (10.3%) (Text-fig. 19B) is third in abundance and is discussed below.

DISTRIBUTION: Samples containing this fauna are uncommon along the northern edge of Florida Bay. They are scarce because as soon as the sea reaches into the Everglades the nonmarine elements are quickly swamped by marine shells. Samples from within the Everglades and from peat layers formed by the Everglades in the past both yield this assemblage. There are other nonmarine shells, but they are never abundant enough to serve as Key Taxa.

Mud Flat Biofacies

KEY TAXA: *Truncatella* (which here includes both *T. pulchella* and *T. bilabiata*) (41.4%) (Text-fig. 20A, B) and Gastropod 2482 (27.0%). *Cerithidea costata* (7.4%) (Text-fig. 20D), discussed more fully below, rounds out the first 75% of the faunal count. Other terrestrial forms can also be present in small numbers. Gastropod 2482, a Key Taxon in the Everglades Biofacies, is associated there with large numbers of *Hydrobia* rather than with *Truncatella*, as it is here.

BIOFACIES STRUCTURE: This is the most strongly skewed fauna in Florida Bay. Three quarters of the specimens in these samples come from just the three taxa out of a total of 79. The final 1% contains 40 taxa (50.6%). This is an extremely skewed, leptokurtic distribution.

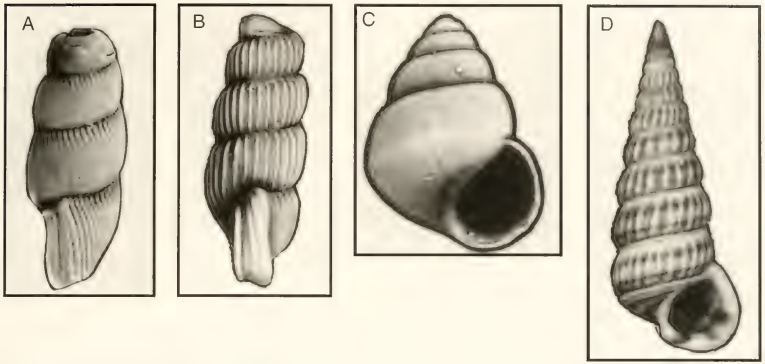
DISTRIBUTION: This fauna lives on the rock keys from Key Largo southward. It is also found as a residual (relict) biota on a few keys in the Bay. Once a key has been cut off from a new supply of the terrestrial snails, this biofacies is eventually replaced by the Playa Biofacies.

Playa Biofacies

This biofacies develops on mud flats or playas that occupy the interiors of most of the keys in Florida Bay. These flats are subjected to extreme environmental shifts: sometimes flooded by shallow sea- or rainwater (Text-fig. 22) or at other times, desiccated completely (Text-fig. 23). After flooding, the water quickly begins to evaporate, and the salinity rises dramatically. Thus, to survive on these playas an animal must develop mechanisms to keep from drying out or succumbing to high salinity.

DOMINANT TAXA: The gastropods *Diastoma varia* (30.8%) (Text-fig. 21C), *Cerithidea costata* (11.9%) (Text-fig. 21B), and a number of common Central Interior forms, plus the pelecypod *Polymesoda maritima* (2.2%) (Text-fig. 21A).

KEY TAXA: A simple listing of the Dominant Taxa can make this assemblage appear much like a sample from the neighboring marine Central Interior Biofacies. It is the two indigenous taxa, *Cerithidea* and *Polymesoda*, however, that are distinctive. Both have developed ways of coping with the severe periods between floodings.



Text-figure 20.—Most important taxa of the Mud Flat Biofacies. A. *Truncatella pulchella*. B. *Truncatella bilabiata*. C. Gastropod 2482. D. *Cerithidea costata*.

Cerithidea costata has a large circular operculum behind which it can withdraw into its shell, sealing in some water and isolating itself from dryness.

The clam *Polymesoda* can close its two valves tightly, enclosing a little water to keep it from desiccating. Shells can be found on playas with the valves still tightly joined even after the animal inside had died. This is unlike most clams, whose shells automatically open when the adductor muscles relax after death.

INTRODUCED TAXA: Samples from the playas yield many taxa from the adjoining marine biofacies. Inevitably, great numbers of the minute shells of *Diastoma* are washed in during storms, often making it the Dominant Taxon. Samples from keys in the northern part of the Bay yield considerable numbers of such typical Northern or Central Interior taxa as *Anomalocardia, Parastarte, Cerithium muscarum, Retusa* and *Crepidula*. Samples from playas on keys closest to the Everglades usually still yield specimens of *Hydrobia* or *Truncatella*.

The marine and terrestrial shells, however, are irrelevant to the recognition of the Playa Biofacies. The joint presence of *Cerithidea* and *Polymesoda* (and especially of conjoined shells of the latter) are reliable guides. *Cerithidea* is normally more common than *Polymesoda*.

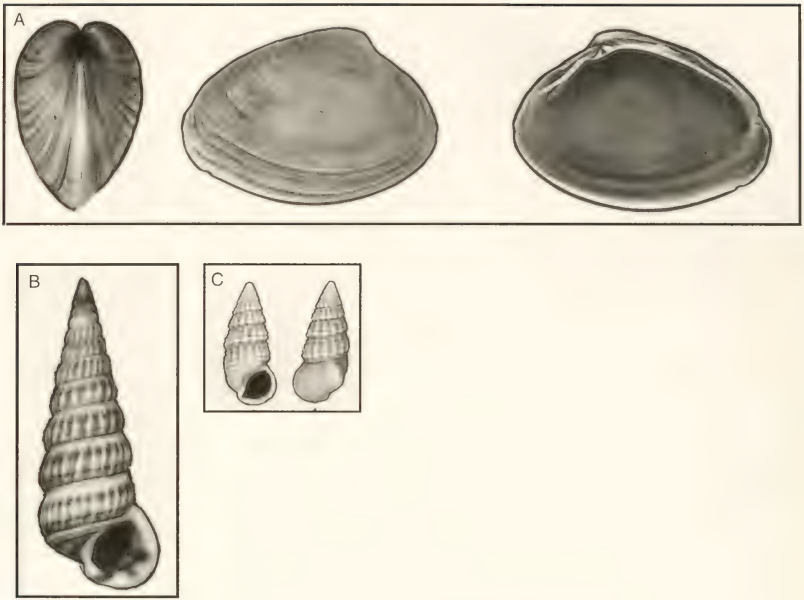
DISTRIBUTION: While we did not map it, we found this biofacies on every key we visited in Florida Bay that has a central mud flat (except for the Arsnicker Keys discussed later). In the early years of the study we visited many keys and found central playas present almost everywhere. In later years, entrance upon the keys was denied so we did not see some keys, mainly in the northwest.

SEPARATION OF THE THREE BIOFACIES: These three biofacies are easily separable with a little experience, but Text-figure 24 illustrates the differences quantitatively, showing the abundance of the five most significant taxa. *Hydrobia* and Gastropod 2482 dominate the Everglades Biofacies. On mud flats, Gastropod 2482 and *Truncatella* dominate, while the playas yield the *Cerithidea-Polymesoda* fauna.

Rocky Shore Biofacies

This is a well known assemblage, primarily of snails and chitons, that clings to rocks in the surf zone. It is developed over large areas far afield from Florida. Because the assemblage is well known and reflects a zone only a few feet wide where rocky shores have developed on the Atlantic side of a few Keys, we made no effort to sample it in detail.

KEY TAXA: This is "the exception that proves the rule" that taxa are generally not restricted to a single biofacies. Six of the twelve forms found here are confined to this unique niche. The most definitive taxa (based on a single sample) are: *Batillaria minima* (43.8%) (Text-fig. 4F), *Tectarius muricatus* (23.6%) (Text-fig. 25A), *Littorina ziczac* (23.1%) (Text-fig. 25C), and *Nerita peloronta* (7.1%) (Text-fig. 25B). *Batillaria* was discussed earlier. In large numbers, it indicates the proximity of a key. When found with common *Tectarius, Littorina* and/or *Nerita*, it indicates that



Text-figure 21.—Most important taxa of the Playa Biofacies. A. *Polymesoda maritima.* B. *Cerithidea costata.* C. *Diastoma varia.*

the key had a rocky rather than a muddy shore. Rare specimens of *Tectarius* were found elsewhere, but *Littorina* and *Nerita* were not.

DISTRIBUTION: All of the keys inside Florida Bay have muddy shores, so this biofacies is found only on the Atlantic side of the rock keys from Key Largo southward, wherever wave action has exposed bedrock.

ENVIRONMENTAL FACTORS

We mentioned in discussing the transition between the Central Interior and Exterior Biofacies that *Transennella conradina* and *Brachidontes exustus* vary in numbers with the depth of water. We also noted a similar depth effect separating *Anomalocardia* and *Parastarte* in the Northern Biofacies. Relationships like this led us to collect data on: (1) depth of water, (2) mud content of the sediments and (3) salinity of surface water.

DEPTH OF WATER

WATER DEPTH AND INDIVIDUAL TAXA: Text-figures 26–28 show the changes in the numbers of *Transennella conradina, Brachidontes exustus* and *Parvilucina multilineata* with depth. Text-figure 26 shows that *T. conradina* increases in abundance with increasing water depth to a maximum at about 8 feet (2.4 m), below which its numbers sharply decrease. Rare specimens have been found to 19 feet (5.8 m). *Brachidontes exustus* (Text-fig. 27), on the other hand, reaches its maximum at about two feet (0.6 m), then holds at counts above 4,000 in two liters of sediment to depths of eight feet (2.4 m) where it, too, abruptly becomes uncommon. We did not find it deeper than 13.5 feet (4.1 m). *Parvilucina multilineata* (Text-fig. 28) has a different pattern. It peaks at a little over four feet (1.2 m), which is deeper than *Brachidontes* and shallower than *Transennella.* Also unlike those two, it

Text-figure 22.—A flooded playa on Park Key, January 29, 1970.

gradually decreases in numbers to about 14.5 feet (4.4 m).

These three graphs were selected to show that the numbers of these taxa vary in individual ways with depth of water. In this respect they are surrogates for all taxa for which adequate data are in hand. Each has a "preferred" depth, but the fact that a taxon is not abundant everywhere at this depth shows that depth alone does not completely control taxon distribution. Both *T. conradina* and *Brachidontes* are most abundant at depths of about eight feet (2.4 m), but not in the same places (Text-figs. 9, 11).

WATER DEPTH AND BIOFACIES: Just as depth does not completely control the distribution of any taxon, neither does it control the distribution of the biofacies by itself. Text-figure 29 is a plot of the range of depths at which we found each of the marine biofacies. The bars are arranged in order of increasing depth of its shallowest appearance. This arrangement does *not* duplicate the order of biofacies outward from the Everglades to either the open Atlantic or the Gulf of Mexico, indicating that biofacies are not simply depth-controlled.

Mud Content

After some misguided early efforts to apply conventional sieve analysis to muddy Bay sediments we adopted Ginsburg's convention of defining "mud" as that portion of the sediment smaller than one eighth of a millimeter.

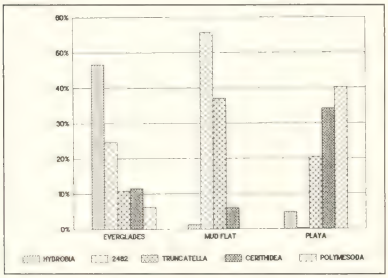
MUD AND WATER DEPTH: Unfortunately, facilities for measuring mud content were not readily available in the early years of the study, so we have data on fewer samples than we would have liked. We have enough information, however, to demonstrate that mud is more characteristic of shallow water than of deep, but more work needs to be done on deeper and coarser sediments. Most areas in the southern Bay yield sandy sediments with a low mud content, and we did not sample them adequately.

Text-figure 30 shows an abrupt reduction in mud content where water depth exceeds four feet (1.2 m). All samples that contained more than 75% of mud were from waters shallower than that depth. More analyses are needed to document the changes below four feet, for the data in Text-fig. 30 can be interpreted

Text-figure 23.—A dry playa on Park Key, October 19, 1970.

in several ways. Present information, however, is sufficient to show that high mud content is a feature of shallow water, not of deep water.

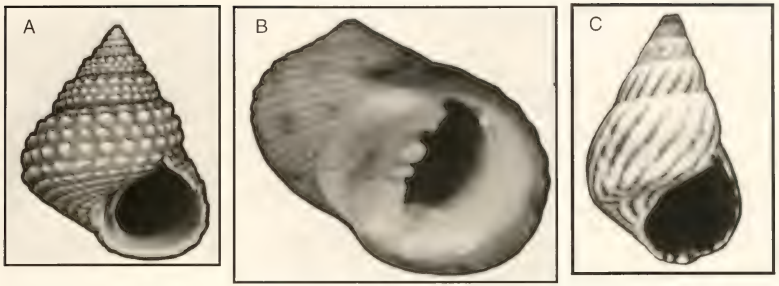
MUD AND BIOFACIES DEVELOPMENT: An obvious question was whether some biofacies are closely tied to mud content. Unfortunately, most of our early samples were studied at a time when sediment analyses were not readily available. More data would be desirable, but some general patterns are apparent.



Text-figure 24.—Comparison of the relative abundance of five critical taxa from three of the quasimarine biofacies: Everglades, Mud Flat, and Playa.

Text-figure 31 is similar to Text-figure 29 in form. It shows the observed ranges of mud in seven of the marine biofacies. It is based on 54 samples typical of a single biofacies and 19 samples transitional between two biofacies. As before, transitional samples are included in the bars for both biofacies. The number of analyses from single biofacies and transitional samples is shown below each bar. Unlike Text-figure 29, however, the bars are arranged in the order of appearance of the biofacies outward from the edge of the Everglades.

Text-figures 29–31, studied together, make clear the independence of the biofacies from controls by any single environmental factor we studied. For example, the *Parastarte* Subfacies is confined to shallow water (Text-fig. 29), where mud is abundant (Text-fig. 30), so it follows that the mud content of the sediments in which the *Parastarte* Subfacies occurs is the highest of the seven plotted in Text-figure 31. In contrast, *Tri-*



Text-figure 25.—Most important taxa of the Rocky Shore Biofacies. A. *Tectarius muricatus.* B. *Nerita peloronta.* C. *Littorina ziczac.*

colia Subfacies samples range from depths of less than one foot, where mud is abundant, to nearly 20 feet (6.1 m), where mud is virtually absent.

MUD IN CORES: We analyzed a number of core samples for mud content, but they showed that once sediment has been covered deeply enough to prevent further agitation, most of the remaining porosity is filled by mud sifting down from above. As a result, core samples contain more mud than sediments at the sediment-water interface. For this reason we only used sediment analyses from the topmost sample of any core for this study.

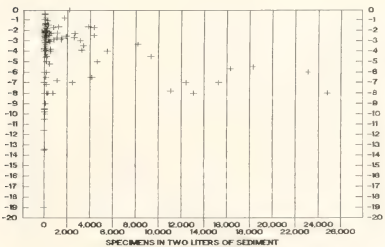
To summarize, the available data show that there is association between mud and the marine biofacies but that mud content alone does not control biofacies distribution.

Salinity

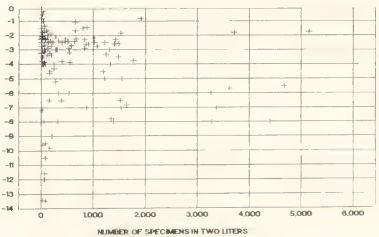
THE PROBLEMS: Salinity proved to be the hardest of the environmental factors to treat. First, there is the problem of measurement. A complete laboratory analysis of salinity is laborious and involves high temperatures at which some solutes are vaporized. We were not equipped to do this.

In the field we used the more easily measured chlorinity as a substitute estimate of salinity. The Amoco Research Center laboratory was equipped to determine total dissolved solids (TDS), and we shipped about 20% of our water samples there for verification. The two measurements confirmed each other. In 1983 and 1984 we collected quarterly samples of surface waters over the entire Bay and shipped them to the laboratory for TDS analysis.

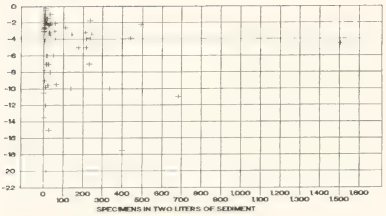
Our second problem was to define "normal salinity" in and around Florida Bay. The open oceans are by no means uniform, but they tend to have salinities in the range 36–39 parts per mille (ppm). On the reef tract, outside the rock keys, salinities ranged around 34–36 ppm during the years of our study. Within the Bay, "normality" must be hedged with qualifiers



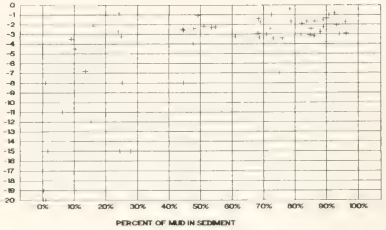
Text-figure 26.—Depth vs. abundance for *Transennella conradina.*



Text-figure 27.—Depth vs. abundance for *Brachidontes exustus* Based on 170 samples.



Text-figure 28.—Depth vs. abundance for *Parvilucina multilineata*.



Text-figure 30.—Mud content of sediment vs. depth of water in feet. Based on 65 samples.

about temperature, rainfall, distance from land, season of the year, *etc.* In the Bay, "normal" salinity appears to be close to 34 ppm at those times of the year when there is neither strong evaporation or heavy dilution by freshwater runoff from the Everglades.

At most places we sampled only surface water. Surface salinity is probably only a good indicator of the salinity of water in contact with a living mollusk in shallow water where salinity can be uniform through the water column. In many parts of the Bay there is salinity stratification, although differences are small. Thus, our data should be regarded as only an approximation of the water in which the mollusks lived.

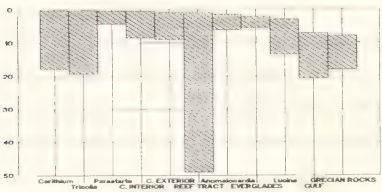
Sources of Salinity Change

Florida Bay is bounded on the north by the Everglades and on the southeast by the very pervious Florida Keys. On the west it is open to the Gulf of Mexico. Geography thus determines two of the three factors that cause salinity in Florida Bay to fluctuate: (1) inflow of saline water from the ocean and (2) inflow of fresh water from the Everglades. The third factor is evaporation.

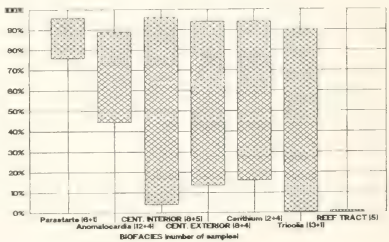
INFLOW OF OCEANIC WATER: It might seem from a glance at the map that the ocean water coming into the Bay would largely flow in from the Gulf of Mexico because there are few barriers in the west. Festooning of the mud and sand bars between many of the keys in the Bay, however, clearly shows that the dominant flow in the southern Bay is from the Atlantic *westward toward* the Gulf of Mexico. Atlantic waters flow into the Bay through many openings in the rock keys, but the strong currents that remove mud from the southern sand bars come through the gaps between Upper and Lower Matecumbe Keys and the still wider openings to the southwest (Text-fig. 13 and others).

The strong currents from the Atlantic limit the influence of the Gulf of Mexico to the far western edge of the Bay where the large mud banks stop at Sandy Key (Text-figs. 18, 41). A tongue of Gulf water also appears to the south of those major banks. The critical importance of this water flow is that the faunas of most of the Bay are more closely akin to those of the Atlantic rather than to the Gulf of Mexico.

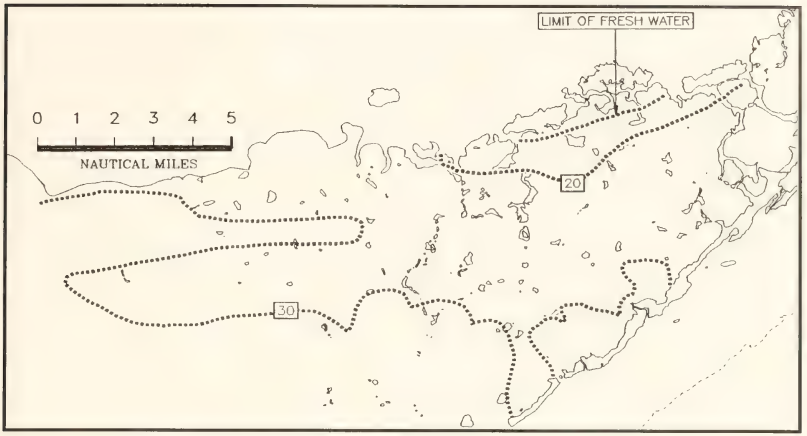
INFLUX OF FRESH WATER: Both the northern



Text-figure 29.—Depth ranges of the marine biofacies. In making this plot, we had data on the depth of water on 151 typical samples. Thirty more samples were transitional between two biofacies and one, among three. All transitional samples are included in both (or three) biofacies bars. In only one case a transitional sample extended the limiting depth range, but by less than six inches (12.7 cm).



Text-figure 31.—Ranges of mud content in seven marine biofacies. Based on 54 + 19 samples (see explanation in text).



Text-figure 32.—Limits of salinity dilution by influx of fresh water. 1 nautical mile = 1.852 kilometers.

and interior parts of the Bay are affected by fresh water from the Everglades. Almost all of the area where mud banks exist can at some times have salinities lower than the "normal" 34 ppm. Beyond the areas of bank development, the inflow of oceanic water limits the amount of dilution by fresh water.

EVAPORATIVE CONCENTRATION: During the warmer months, evaporation raises Bay salinities in many places. During this study we found salinities up to 60 ppm in the bays along the edge of the Everglades, but the recovery of crystals of both calcite and anhydrite from some cores along the northern edge of the Bay shows that concentrations have exceeded 90 ppm at times.

Thus, depending on location, faunas can be subject to wide shifts in salinity up to 60 ppm along the Everglades to changes of less than five ppm in the southern "flume", where water enters from the Atlantic.

Expressing the large amount of salinity data was our most intractable problem. Simply plotting salinities on a map proved meaningless unless maps were separated as different seasons. Maps of selected taxa with associated salinity measurements had the same problem. Contouring of minima, maxima or averages gave such complex patterns that even the sophisticated contouring programs on Amoco computers could not make sensible maps of them. In the end, Text-figures 32 and 33 present the data in the most meaningful way we could devise.

Text-figure 32 shows the effects of dilution by water from the Everglades. It shows the farthest limits at which we found (1) fresh water, (2) water diluted to a salinity of 20 ppm and (3) slightly diluted water of 30 ppm. Beyond the 30 ppm contour Bay waters were not much different from the "normal" Bay salinity near 34 ppm.

Text-figure 33 is the contrasting map showing the limits at which we found waters concentrated by evaporation to salinities of 45 and 55 ppm. We found waters up to 60 ppm north of the line marked "55".

Salinity and Depth of Water

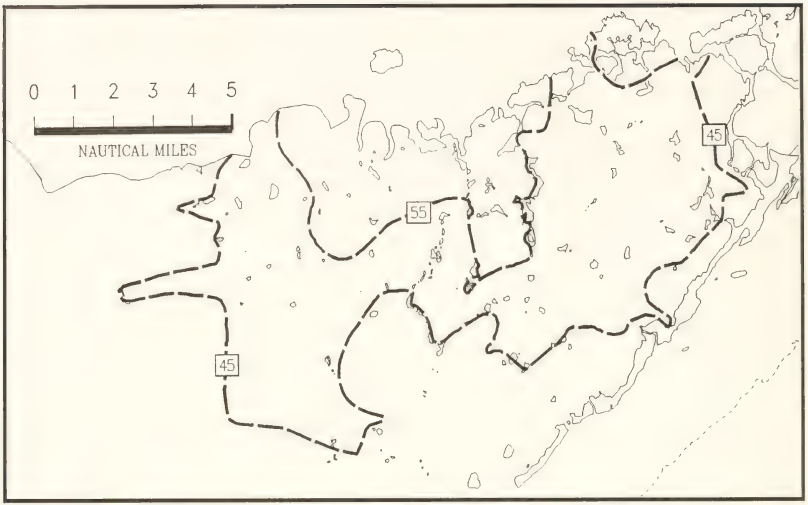
It should come as no surprise that changes in salinity occur in concert with water depth. At all locations where we found the difference between the freshest and most saline water to equal or exceed 30 ppm, the water was six feet (1.8 m) or less in depth.

Salinity and Mud Content

Inasmuch as ranges of salinity are greatest in less than six feet (1.8 m) of water and mud content also increases in shallow water, it follows that salinity and mud content are highly correlated. This does not prove a causal relation between the two.

Ranges of Salinity and Taxon Abundance

We made comparisons of the abundance of every taxon common enough to have statistically adequate



Text-figure 33.—Selected limits of evaporative concentration. 1 nautical mile = 1.852 kilometers.

sampling against its associated range of salinity. Three major groups of taxa emerged, characterized by salinity ranges of 0–10 ppm, 16–30 ppm and over 30 ppm.

In the end, it became apparent that we had demonstrated the obvious. In the north, where salinities vary widely, there are fewer taxa but larger numbers of individuals. In the central Bay, where swings in salinity are less, there are more taxa but fewer individuals of each taxon. And in the areas of open water where there is minimal salinity variation, there is a maximum number of taxa, many of which are rare. All of this is obvious from the sample counts alone, and it is general biologic knowledge that fewer animals will live where the environment is difficult than where it is equable.

Durbin Tabb, who studied the living mollusks of the Bay, told me more than 30 years ago that *Transennella* does not tolerate salinity swings even though it reaches its maximum abundance in Central Interior areas where salinity varies considerably. Instead of being adapted to tolerate these swings in salinity, it reproduces quickly when it senses a change, thus assuring that there will be another generation the next time the salinity returns to levels it finds tolerable. This single case made it clear that we cannot rely on shells alone (which are all that is available to the paleontologist or geologist) to interpret past salinity environments.

APPLICATIONS OF THE BIOFACIES

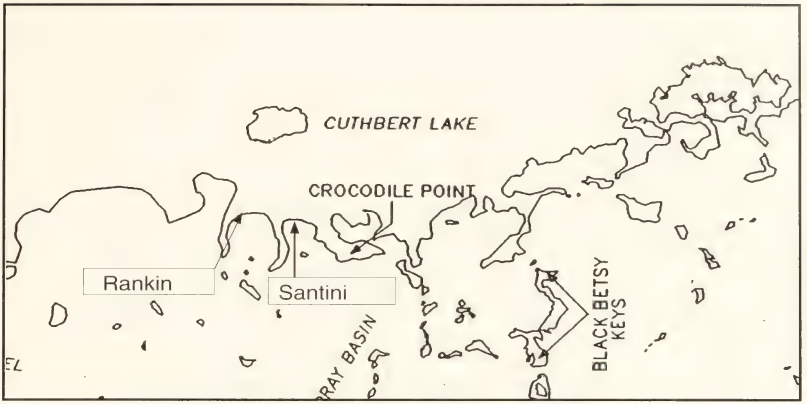
The first purpose of this investigation was to develop a field method for differentiating the molluscan biofacies of Florida Bay. For this, we developed a display on which shells can be placed and evaluated directly.

A second objective was to analyze core samples to see whether analysis, using the biofacies that we had established from surface samples, would provide a coherent and intelligible record of historic changes at any given spot in the Bay.

On the way to accomplishing these two tasks we also developed a computer spreadsheet program (FACICALC) that makes use of all of the taxa identified in the study. This laboratory program permits more refined biofacies evaluations and provides numerical values that reflect the degree of similarity of each sample to each biofacies. It is the basis of both the biofacies descriptions given earlier and the maps of Text-figures 6, 9, 11, 13, and 18.

THE "BINGO BOARD"

For field use we created a plastic board bearing photographs of Key and Dominant Taxa of various bio-



Text-figure 34.—Location of cores from Rankin and Santini Bights.

facies. Seminar participants collected shells, identified them, and placed them on the corresponding photos on the Bingo Board. After all of their shells were on the Bingo Board, the total number of specimens of each taxon was multiplied by a factor based on the frequency of each taxon in each biofacies. These weighted numbers were summed for each biofacies, and the biofacies with the highest total identified the biofacies of the sample.

As the participants identified the taxa, the board became covered with small piles of shells, which led one anonymous geologist to call the game "Shell Bingo", and the name stuck. By association the board has been called the "Bingo Board" ever since. Appendix 2 gives the basic instructions for creating a Bingo Board.

Laboratory Studies

Sample study in the laboratory is more precise than Bingo Board estimates because it weighs all taxa, including those too small or too rare for field use and because the counts are based on quantitative sampling.

Transitional Samples

As pointed out above, none of the biofacies is sharply delineated at its boundaries. Each grades into its neighbors over some limited distance. Samples taken in these transitional areas show similarities to two, or, rarely, even three adjacent biofacies. Such samples are of great value in mapping the boundaries between biofacies. In preparing the maps shown here we have regarded samples whose content differed by less than 2.5% as transitional.

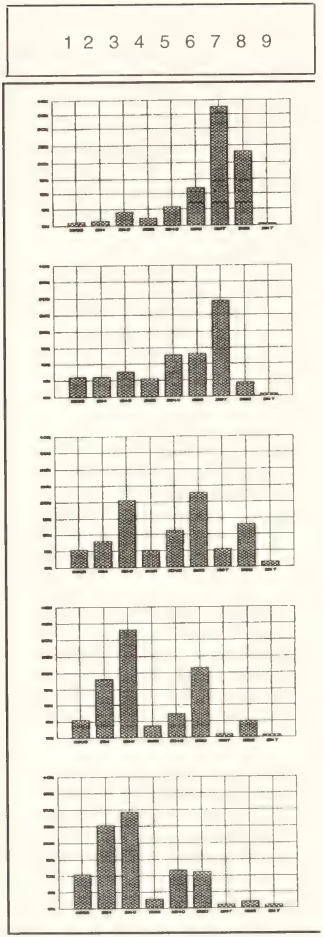
Core Studies

As mentioned earlier, our definitions of the marine biofacies are based on analyses of surface samples. The core samples were viewed as problems to be solved and not as part of the definition of the biofacies. The two studies detailed below show how surface evidence works in evaluating historical changes in cores.

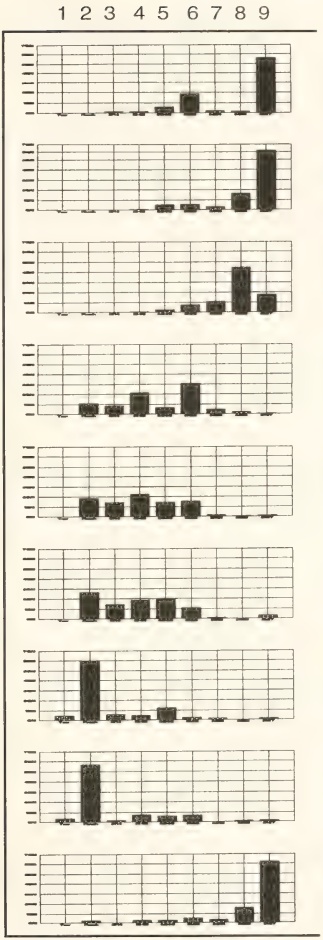
The Santini Bight Core

This core, from the head of Santini Bight (Text-fig. 34), was 95 cm long, but the lower end had a "frayed" appearance suggesting that the bottom of the core was incomplete. The lack of a peat layer usually found in cores from this area also suggested a missing piece. The entire core was composed of uniform gray mud that showed no structures or natural breaks, so we sampled it in arbitrary increments of 20 cm, except for the basal 15 cm (Text-fig. 35).

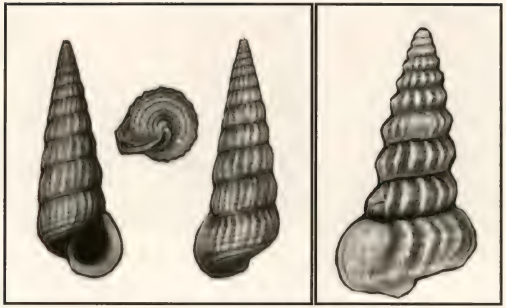
The bottom sample (80–95 cm below the top of the core) is dominated by the characteristic pair of Playa Biofacies taxa *Polymesoda* (3) and *Cerithidea* (2). In the 60–80 cm interval the same pair is still Dominant, but the percentage of fresh water snails (1) has dropped and that of *Anomalocardia* (6) has risen, indicating a lessened Everglades and a greater marine influence. The modest increases in both *Cerithium*



Text-figure 35.—Description and taxon abundance in the Santini Bight Core. The vertical axis on the graph for each segment of the core reflects the original percentage of each taxon in the total sample for that segment. The height of each Y-axis is 70%. The vertical lines provide a guide for the eye in comparing taxa from one graph to the next. These lines, numbered 1 through 9 at the top, refer to the following taxa: 1—Fresh water snails (overwhelmingly *Hydrobia*); 2—*Cerithidea costata*; 3—*Polymesoda maritima*; 4—*Cerithium muscarum*; 5—*Retusa candei*; 6—*Anomalocardia auberiana*; 7—*Parastarte triquetra*; 8—*Transennella conradina*; 9—*Brachidontes exustus*.



Text-figure 36.—Description and taxon abundance in the Rankin Bight Core. The scale on the left side of each graph is 0–70% (horizontal lines). The percentages are those of the taxa in the whole sample. The numbers 1–9 at the top of the upper graph represent the following: 1—Terrestrial snails (*Helisoma, Polygyra*); 2—Fresh water snails (overwhelmingly *Hydrobia*); 3—*Cerithidea costata*; 4—*Polymesoda maritima*; 5—*Retusa candei*; 6—*Anomalocardia auberiana*; 7—*Cerithium muscarum*; 8—*Crepidula fornicata*; 9—*Parastarte triquetra*.



Text-figure 37.—Precocious maturity: *Cerithidea costata.*

muscarum (4) and *Retusa* (5) both show an increasing Northern Biofacies proportion.

The fauna of the interval 40–60 cm below the top of the core is dominated by *Anomalocardia* (6), with the Key Playa Taxa (2 and 3) reduced by 50%. This indicates a spread of water over the earlier playa. *Retusa* (5) and *Parastarte* (7), both characteristic Northern forms, are more common. The larger percentage of *Anomalocardia* as compared to *Parastarte* is definitive of the *Anomalocardia* Subfacies.

In the upper two samples, the water has become shallower, and *Parastarte* is the overwhelmingly Dominant Taxon, reaching over 60% of all specimens in the sample from 20–40 cm. The top sample, however, also shows a quadrupling of *Transennella conradina* (8), indicating an increasing influence of what will become the Central Interior Biofacies if the advance of Bay flooding drives the Everglades still further north. The short bars for *Brachidontes exustus* (9) have been included to show that while that shell is generally present, it is nowhere common; the Central Exterior Biofacies is still too far away.

The Rankin Bight Core

This core was taken at the head of Rankin Bight (Text-fig. 34). The surface sample was taken by shovel; the rest are core samples cut at the depths shown in Text-figure 36. The descriptions of the sediment are the original field observations. The upper 100 cm of gray mud in the core appeared to be uniform and were cut arbitrarily at 20 cm intervals. Below 100 cm we used natural breaks in the sediments above and below the peat layer at 126.5–134.5 cm. The basal marly layer was distinctly more indurated than the gray mud of the top 100 cm.

At 139–141 cm below the top of the core a slightly indurated marl appears to reflect an early shallow flooding by the sea. In cores from this area we normally see a basal peat layer with an Everglades biota overlain successively by more marine sediments as continuing inundation displaced the Everglades northward. In this core, however, we see a fragment of an early flooding by shallow water containing *Parastarte* (9) in abundance.

The interval 126.5–139 cm reflects the gradual readvance of the Everglades, which is indicated by (A) the development of peat, (B) the replacement of the older *Parastarte* fauna by an Everglades Biofacies dominated by *Hydrobia* (2) and (C) the presence of small numbers of terrestrial snails (1).

From 126.5 to 117 cm the Everglades influence decreased, as shown by the increasing amounts of mud *vis-a-vis* peat. *Hydrobia* (2) still persists as the most common faunal element, but *Cerithidea* (3) and *Polymesoda* (4), the indicators of Playa conditions, suggest that the Everglades were moving away again. *Anomalocardia* (6) has increased, also indicating marine encroachment.

In the interval 100–117 cm, *Polymesoda* (4) and *Cerithidea* (3) have become the Dominant Taxa while *Hydrobia* (2) has diminished further. This indicates a Playa environment like that seen today where the mangroves have moved back from the edge of the Everglades and exposed the ground. This sample is a transitional one. FACICALC analysis shows that this sample is almost equally weighted between the Everglades and the *Anomalocardia* faunas. Shorter sample intervals would probably have found truly transitional samples.

At 80–100 cm we see an interval of the most open

water in this story, where *Anomalocardia* (6) dominates. This, together with the decline of the taxa immediately to its left in the graphs, suggests the presence of a shallow "lake" like that seen in many places just south of the existing Everglades. The abundant *Anomalocardia* suggest a water depth of 2–3.5 feet (50–90 cm).

The interval 60–80 cm was not counted, but it contained an *Anomalocardia* Subfacies fauna.

The 40–60 cm sample is instructive because it shows how the Ubiquitous Taxa might mislead us. The graph needs to be viewed as if the tall bar for *Crepidula* (8) were not there. That taxon does not help to interpret the story. Instead, the bar for *Parastarte* (9) is more important, leading as it does to the dominance of the taxon in the two samples above.

The slight increase in *Polymesoda* in the surface sample could reflect a slight deepening in most recent times. This is also consistent with the slight decrease in the percentage of *Parastarte* in the surface sample.

The two cores represented in Text-figures 34 and 36 are mutually supportive in their stories. The 95 cm of the Santini Bight core appear to equate well with the Rankin Bight core down to 117 cm. Both intervals have indistinguishable gray muds, both start in a Playa Biofacies, go briefly through the *Anomalocardia* Subfacies and terminate in the *Parastarte* Subfacies. The parallelism also lends credence to the inference that the Santini core was incomplete. Other cores have been diagrammed in this way, and all have yielded interpretable stories of the evolution of various parts of the Bay.

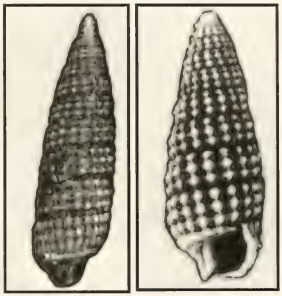
MISCELLANEOUS OBSERVATIONS

Precocious Maturity

As mentioned above, Durbin Tabb told me many years ago how *Transennella* responds to changes in salinity by maturing quickly and reproducing before the onset of an unfavorable environment causes its death. His comment led me to wonder whether this was an isolated phenomenon in this pelecypod or a more general molluscan characteristic.

Transennella does not show distinctive physical signs of sexual maturity on its shell, but some pelecypods and many snails do. Therefore, if the ability to mature precociously is generally present among mollusks we should find both large and small shells showing these mature structures.

The first shell for which I found both large and small mature shells was the snail *Cerithidea*. Its maturity is signaled by a flaring of the aperture outward from the earlier plane of the shell. Text-figure 37 shows two mature shells: the one on the left is 31.7 mm tall while that on the right is only 5.7 mm.



Text-figure 38.—Precocious maturity: *Cerithiopsis greenii.*

Text-figure 38 shows another gastropod, *Cerithiopsis greenii.* This is a smaller shell in which maturity manifests itself by a narrowing of the final whorl. The shell on the left is 5.0 mm. tall, while that on the right is only 1.7 mm high. Mature shells taller than 5.0 mm were seen during the study.

Even the tiny shells of *Caecum,* in which maturity is expressed by a narrowing of the apertures at the mouth of the shell, show this same characteristic.

This is not the place to pursue this idea at length, but it has some implications for molluscan taxonomy. It also bears on the origin of some enigmatic assemblages, known as "dwarf faunas". These are made up mainly or entirely of minute but fully formed shells whose origin has long been a paleontologic puzzle.

Postmortem Shell Movement

When I originally undertook this study I hoped that developing an adequate body of quantitative data would permit reconstruction of the details of the original living fauna. As part of this inquiry, my assistants and I for many years kept counts of the number of right and left valves of clams. In the end, my hope of describing the living fauna from the shells alone proved illusory, but the valve counts provide interesting information on the amount of sorting that takes place among dead shells. The details of this study can be found in Appendix 3.

To summarize the data, the numbers of right and left valves recovered from any free-living (*i.e.,* unattached) pelecypod were not found to be statistically different when we had counted an adequate number of specimens. This suggests strongly that, after death, the valves of each pelecypod tend to remain essentially in

Text-figure 39 — Dr. Kenneth W. Cirlacks pointing to a beach ridge on Park Key

place, subject only to the minor movement caused by bottom dwelling scavengers and to local movements of the bottom of the water column.

Two factors that can cause disparate valve counts appear to be:

(1) Pelecypods in which one valve is cemented or otherwise attached to a substratum. Such pelecypods are normally represented only by the free valve.

(2) Pelecypods in which the crystalline structure of one valve is significantly more fragile than in the opposite valve tend to be unequally represented. The principal example of this is *Pinctada,* in which the right valve is weaker.

The conclusion that there has been little post-mortem transportation of pelecypod shells leads directly to the next topic: How far do storms transport shells?

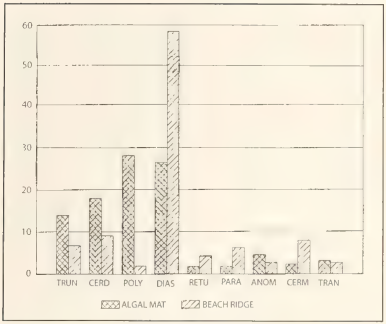
Storm Transport of Shells

Movement of shells by storms has long been a matter of debate within the paleontologic community. On one hand, there are those who feel that such movement is, at best, a local phenomenon that forms shell coquinas. On the other side are those who have invoked transportation of entire biotas from the area where they formed to remote areas where they appear as an exotic addition. Our valve counts imply that, as a rule, little individual shell transportation takes place, but it does not by itself preclude mass transport of entire biotas.

Florida Bay offers some direct evidence on shell movement during severe storms. The Bay has experienced many hurricanes, so there is firsthand evidence on the shell-moving ability of these great storms.

The present day beaches on the keys provide one piece of direct evidence. Text-figure 39 shows a storm-built beach ridge on Park Key. It rises about two feet (0.6 m) above the level of the water and consists of the comminuted shell debris characteristic of beaches. The width of the beach ridge shown in the figure is typical; generally, the distance from the top of the ridge to the point where the key's central playa replaces the beach is nowhere much more than 25 feet (7.6 m) and in most places is less.

Text-figure 40 compares some taxa from the algal

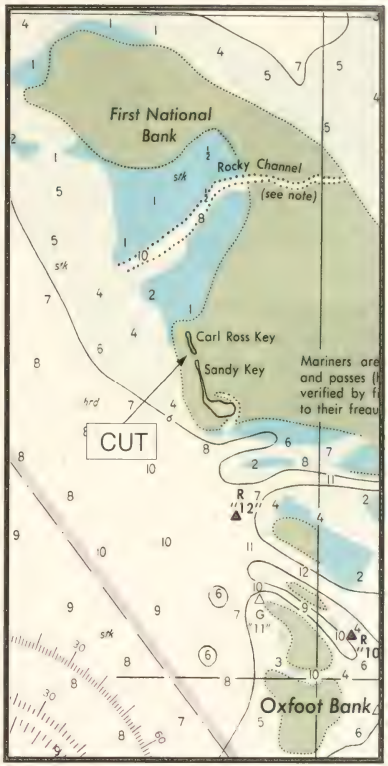


Text-figure 40.—Comparison of taxon abundance on algal mat and beach on Park Key. The left side of each double bar (cross-hatched) shows the frequency of the taxon in the algal mat. The right side of the bar (diagonal lines) shows its frequency in the beach ridge. The scale on the Y-axis gives the percent of each taxon in the entire fauna. The three taxa on the left are those that typically characterize playas, mud flats and non-marine environments. The six on the right are more typically marine. From left to right on the chart they are: TRUN—*Truncatella*; CERD—*Cerithidea*; POLY—*Polymesoda*; DIAS—*Diastoma*; RETU—*Retusa*; PARA—*Parastarte*; ANOM—*Anomalocardia*; CERM—*Cerithium muscarum*; TRAN—*Transennella conradina*.

mat on the upper surface of the playa on Park Key with taxa from the beach ridge that is its lateral equivalent. The algal mat formed the top 3 cm of a core cut on the playa. The beach ridge was sampled by shovel.

There are nine taxa, each represented by a paired bar. The bars are clearly divided into two disparate groups. On the left, the distinctive *Cerithidea/Polymesoda* Playa assemblage dominates. On the right these taxa are of minimal importance. Dividing the array is the bar for *Diastoma*. Because of its small stout shell it is the only marine form that is carried unbroken in significant numbers onto the land during storms. Larger shells are either too heavy to be mobile or are ground up to make the characteristic "shell hash" of the beach ridge. Because of the breakage of other shells, *Diastoma* often becomes, by default, the most common shell recognizable in beaches, as it is here. On the right side of the array, the remaining five taxa are all marine forms. They are of relatively low abundance in the beach ridge because *Diastoma* is so dominant.

These samples show that even severe storms carry only a biased and insignificant fraction of the marine fauna onto the land, and even the transported material is mainly confined to the immediate beach area. Faunas even 100 feet (30.5 m) inland are not fundamentally altered by additions from the sea.



Text-figure 41.—Hydrographic chart of the area between Sandy Key and Oxfoot Bank. Reproduced from Chart 11451, National Oceanic and Atmospheric Administration.

Sandy Key (Text-fig. 41), the westernmost key in the Bay, also provides some implicit evidence on the question of mass transport. Shortly before our first visit there in 1964 a severe storm had crossed the island, cutting it in two. Later, the northern segment was renamed Carl Ross Key. At the time of our first visit, the cut through the island (Text-fig. 42) was still a raw unvegetated swath floored only by shell debris. We

Text-figure 42.—A storm cut (between arrows) through Sandy Key; photographed May 31, 1964.

took a sample from this cut and found the *Parastarte* fauna. The Dominant Taxa are: *Parastarte* (23.4%) and *Crepidula* (19.7%). Although Gulf Biofacies shells were only yards away, the three distinctive Gulf taxa are rare: *Corbula* (1.4%), *Nucula* (1.3%) and *Nuculana* (0.8%). These three shells are small and might be expected to have moved easily in a storm severe enough to bisect the key itself. They did not.

In summary, there is no convincing evidence from Florida Bay that storms have a significant ability either to move shells generally or to carry them any distance. Conversely, there *is* evidence of selective transport of the smallest shells, but only over short distances.

Compaction

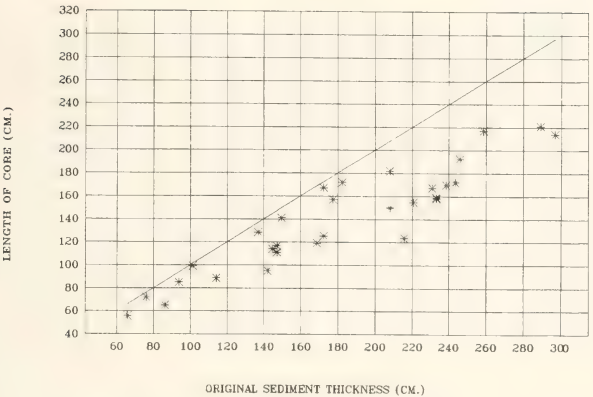
There is a belief among both paleontologists and geologists that lime muds compact very little in the course of lithifaction whereas shales compact a great deal. This is based in part on the observed fact that fossils preserved in shale are generally flattened while those found in limestone are not. This study found evidence, more or less inadvertently, that this simple concept is inadequate.

At most places where we took core samples of the Bay sediments we also probed to find out how thick the sediments were in order to get an idea of the topography of the underlying bedrock. In the early days of the study most of our cores were short and were sent to the Amoco laboratory for extrusion and sampling. In later years, however, we began to take longer cores that we could not practically ship home.

It became apparent that even before the longer cores were extruded they were not so long as the measured sediment thicknesses. Even more, we saw that extrusion further shortened the cores. So we started to measure the length of the unextruded sediment in the plastic core tubes and the length of the sediment cores after extrusion. We found that there was far more compaction in muddy carbonate sediments than the received wisdom suggests.

Of course, some cores were incomplete and short, but in many cases the expected basal peat or fragments of bedrock were present to demonstrate the completeness of the cores. The amount of compaction was far from uniform, ranging from a low of about 2% up to one-third. All cores that indicated greater compaction than this exhibited some features that suggested that they were incomplete and are not included in Text-figure 43. The implication of this admittedly inadequate test is simply that there is much more to be learned about how much compaction can take place in carbonate sediments.

We would expect that when cores can be taken from the sandier sediments of the southern part of Florida Bay they will show less compaction. Further analysis of the mud content throughout the core would also



Text-figure 43.—Comparison of original sediment thickness (X) with length of recovered cores (Y).

make the figures more intelligible, but we did not do this in our study.

ARSNICKER DOME

This name is given here to an unusual arching of the rock floor of Florida Bay around the Lower Arsnicker Keys. Topographically, the Dome rises about ten feet (3.0 m) above the sea floor surrounding it. The water over it shallows to about 1.5 feet (45 cm) (Text-fig. 44), making it a hazard for the unwary boatman who expects deep water in this part of the Bay. The name of the Keys implies the hazard.

There was not time for detailed mapping of the Dome, but it deserves further investigation. Its shape suggests salt movement at depth because it appears much like some of the known hills over salt domes elsewhere along the Gulf Coast.

From first sight, it is apparent that these keys are different from others in Florida Bay. The largest of the Lower Arsnickers (Text-fig. 45) shows an elevated and eroded scarp instead of the gently shelving beaches found elsewhere (Text-fig. 39). On the flanks of the Dome, the small subsidiary keys also expose elevated and eroded cross sections of the muds of which they are composed (Text-fig. 46). After scrambling up onto the largest key, one immediately sees a major difference. The center of this key is not a playa. Instead, there is a field of waist high grass unlike anything on other keys in the Bay (Text-figs. 45, 47, 48). The mollusks here show that this is an out-of-place Mud Flat Biofacies. A shovel sample taken at the foot of the scarp shown in Text-figures 45 and 47 yielded 2,947 shells.

There is some admixture of the local marine fauna, but the Dominant taxa are Gastropod 2482 (1,680 shells = 57.1%), *Truncatella* sp. (125 shells), *T. pulchella* (23 shells) and *T. bilabiata* (750 shells = 30.5%), *Cerithidea* (178 shells = 6.0%), *Polygyra volvoxis* (57 shells = 1.9%), *Cerithium lutosum* (21 shells = 0.7%), *Physa heterostrophia* and *Pseudosuccinea columbella* (both with 17 shells = 0.6%). There were no *Hydrobia*. All of these are nonmarine taxa, except *Cerithidea* and *Cerithium lutosum*. This would be an Everglades fauna if it contained significant numbers of *Hydrobia* and fewer *Truncatella*. As it stands, this assemblage is characteristic of the grassy mud flats found at the southern edge of the Everglades, especially where the mangroves have been stripped away by storms or encroaching seawater.

Recovery of a datable peat sample would have made reconstruction of the history easier, but the details cited above suggest the following. At some point in the past the Everglades extended as far south as the present position of the Arsnickers. As the sea encroached on the area the Everglades Biofacies was displaced by a Mud Flat assemblage. Before the flat could be eroded or buried under marine sediments, the area arched upward sufficiently to preserve the grasses and associated mollusks of the Everglades biota from being overwhelmed by marine conditions. Then, as the sea moved away to the north, Arsnicker Dome stayed high enough above sea level to preserve its relict assem-

Text-figure 44.—Shallow water over Arsnicker Dome. The mangrove seedling is growing in only a few centimeters of water.

Text-figure 45.—A general view of the shoreline scarp on the largest of the Lower Arsnicker Keys; photographed November 18, 1978.

Text-figure 46.—An elevated and eroded scarp on the edge of the small key southwest of the largest Lower Arsnicker Key; the scarp is nine inches (19.0 cm) high; photographed October 7, 1984.

Text-figure 47.—A scarp on the largest Lower Arsnicker Key capped by high grass.

Text-figure 48. Interior of the largest Lower Arsnicker Key showing its unique grass cover.

blage ten or more miles (16.1+ km) from the nearest existing comparable mud flats. It is quite possible that there has been more than one period of arching that fortuitously kept the Dome out of the reach of the sea. A thorough analysis of cores from these keys would probably answer this question.

"RARITY"

This report has dealt mainly with the most abundant taxa in Florida Bay, but there is a large group of taxa that are, by any definition, "rare". We used slightly over 300 taxa that were well enough represented in our samples to identify with reasonable certainty, but when the study ended there were still some incomplete specimens that we could not describe adequately. These fragments appeared to represent about thirty additional mollusks. So our taxonomic base is certainly incomplete.

Much statistical thinking has gone into the problem of estimating the correct proportions of rare items in a population. Good (1953) reviewed some of the postulated solutions. I am also indebted to Dr. Cuthbert Daniel, consultant to Amoco Production Research, for his guidance in the arcane niceties of this field. Dr. Franklin Kemp, of Amoco, (written communication, November 9, 1983) contributed some most useful insights to the question of how reliably we can estimate the frequencies of rare taxa.

In this report we have emphasized the commoner shells, but rare shells are of importance both scientifically and, more recently, as a matter of public policy. Some environmentalists have equated rare organisms, which are a subject for scientific and biologic inquiry, with "Endangered Species", which have become a legal and political matter. Our study has some bearing on this dichotomy.

We used 329 taxa in our calculations, including 326 individual taxa and three larger taxonomic groups: *Polygyra, Truncatella* and *Gastrocopta.* These groups include seven individual taxa, bringing our total set of defined taxa to 333 (326 + 7). The 16 rarest taxa are represented by 14 single specimens from quantitative samples plus two individuals picked during "10 Fraction" sampling. One unique taxon is from a core sample. We identified 393,080 specimens from 190 surface samples and 133,446 specimens from 99 core samples—a total of 526,526 specimens from 289 samples. Other samples (Table 1) do not bear on this question. Dividing the specimen counts by the number of samples gives us an average of 2,000 to 2,100 specimens per surface sample and about 1,350 shells per core sample.

Two questions can be asked about rare taxa:

(1) How many specimens must we count to be certain of finding at least one specimen of a taxon at a specified level of confidence (which I would routinely set at 99%), and

(2) Given realistic limits on the size of the samples we can count, how common must a taxon be for us to expect it to be present at least once in our samples at the 99% level?

The answer to the first question is simply a matter of arithmetic, and for taxa as rare as some we find in Florida Bay we cannot, as a practical matter, count samples large enough to be sure of finding them. One example from Dr. Kemp's analysis puts the problem in perspective. In order to be 99% sure of finding at least one specimen of a taxon present at an abundance of 1 in 100,000 counted shells, we would need to count over 400,000 specimens. But the 16 unique specimens mentioned above came from a sample of 526,526 identified shells. Clearly, it is not practical to gain a credible estimate of the true proportions of such rare taxa.

More useful and appropriate to the objectives of our study is an answer to the second question: Given the size of the samples we can practically count, how rare can a taxon be and still rise to a level that we can expect its proportion in our samples to be reasonable estimate of its true proportion in 99% of our samples?

The crucial number is about five in samples of the size we could practically examine. If five or more specimens of a taxon are present in a sample then it is not unreasonable to use that number divided by the total count of specimens in the sample as an estimate of the percentage of that taxon in a population. (Actually, the critical number is somewhere between 4.5 and 5, but counts are always integers, so we can use 5.) For example, five specimens in a sample of 1,000 suggest that the taxon is about 0.5% of the population. Five specimens in a count of 2,000 suggest that the taxon has a frequency of about 0.25%. These rules of thumb are useful but should not be regarded as statistically rigorous.

Returning to the discussion at the beginning of this paper, I stressed the characteristically long tail of the distribution curve by noting the number of taxa in the last one percent of the total taxa. It follows from the discussion in the paragraphs immediately above that the proportions of most of the taxa in these tails cannot be accurately estimated.

The two most thoroughly scrutinized samples in this study were surface samples from the Central Interior Biofacies. The first came from about one mile (1.6 km) west of Butternut Key, and the second, from the playa on Park Key. I counted 20,628 actual specimens (not normalized counts) from the former, yielding 85 taxa, of which 57 were present five or more times. Thus, 28 taxa fell below the minimum threshold of five. From the Park Key playa sample mentioned in connection with Text-figure 40, I identified 10,214 specimens of 81 taxa, of which 53 were present five or more times. By coincidence, 28 of these taxa also fell below the required five-count threshold. These two samples were exceptional in that they were examined to answer some specific questions early in the study. Even in these samples, however, a third of the taxa were still too rare to permit a useful assessment of their abundance. No other sample specimen counts reached 8,000.

In summary, we cannot practically determine the true proportions of very rare taxa. For that reason alone it is improper to equate "rare" with "endangered" as is sometimes done. Rarity is evidence that the taxa are rare, but not that they are in danger of becoming extinct.

A final bit of anecdotal evidence could be instructive. There were 332 taxa used in this study (one taxon was diagnosed but did not occur in any Bay sample). Of these, 52 (15.7%) fall below the minimum count of five. Three of the 52 remain unnamed and have only Amoco numbers assigned. Of the 49 named taxa, 21 were first described between 1758 and 1799; 25 more were named between 1800 and 1899, and only three were described in the twentieth century. Thus, although 49 of these taxa are too rare for us to estimate their correct proportions 46 of them have been found by various students for over 100 years. Some of them, given formal names by Linnaeus in 1758, have been found for over 250 years. They are rare, but they are not extinct.

APPENDIX 1: TAXONOMIC DISCUSSION

The purpose of this section is to present a brief summary of the features of those taxa that are mentioned in the body of the report. The study itself utilized over 300 taxa, but a full redescription of them all would require far more time and space than is available. Full descriptions and photographic documentation of all taxa have been deposited with the Everglades National Park and the Department of Geoscience at the University of Iowa together with complete sets of maps of the distribution of each taxon known at the time the original study ended in August 1985.

As I have stated at many points in the body of this paper, the formal names are presented here for the comfort of those accustomed to Linnaean nomenclature. None of these names was actually used for this study. Only the Amoco Taxon Numbers, as defined in

Text-figure 49.—Cap-shaped or pyramidal gastropods: A, B, *Acmaea antillarum*. C, *Diodora listeri*.

the files housed at the University of Iowa and Everglades National Park, were used during the study and preparation of sample analyses. If the reader believes another name is more appropriate for any taxon used here it will not alter the data or analyses because the taxa were not based on diagnoses in published taxonomic papers.

This Appendix is designed differently from the usual shell guides or taxonomic works. Because the number of shells described is relatively small there is generally no need to make the wide-ranging comparisons among taxa that are required in a definitive study. Therefore, shells are grouped according to their principal external features (ornament, overall shape, coiling-for snails, etc.).

For each taxon the following basic information is provided:

1. The name of the taxon as used in the text.
2. The Amoco taxon number. This is essential for anyone examining the records at Everglades National Park or at the University of Iowa because all specimens are filed by these numbers.
3. A diagnosis, which is a listing of those features that distinguish the taxon. No attempt will be made to present a full morphologic description.
4. Comparisons with similar Florida taxa that are commonly found but are not named in the text.
5. The full Linnaean name, as used in the text.
6. Biofacies in which the taxon has been found.
7. Other remarks.
8. References to commonly available publications with illustrations that fall within the bounds of the Amoco taxon.

GASTROPODA

CAP-SHAPED OR PYRAMIDAL

Acmaea antillarum
Text-figure 49A, B

AMOCO Taxon #.—2088

Diagnosis.—Low-conical limpet with a nearly smooth or faintly ribbed surface and no apical perforation.

Comparison.—Other Florida limpets are generally strongly ribbed and have a perforation ("keyhole") at the apex. Example: *Diodora listeri* (d'Orbigny, 1847) (Text-figure 49C).

Name.—Acmaea antillarum (Sowerby, 1834). Called *Acmaea candeana* d'Orbigny, 1845, until the early 1950s when the latter name was suppressed.

Biofacies.—Found in all except the Northern *Anomalocardia* Subfacies. Most common in the Gulf and *Cerithium* faunas.

References.—Warmke and Abbott, 1961, pp. 40–41, pl. 6, fig. E; Morris, 1975, p. 113, pl. 36, fig. 16; Abbott, 1974, p. 33, fig. 166; Emerson and Jacobson, 1976, p. 39, pl. 17, fig. 10.

NARROW, HIGH-SPIRED SHELLS WITH SIPHONAL NOTCH AT LOWER LEFT OF APERTURE

Batillaria minima
Text-figure 50A, B

AMOCO Taxon #.—2090

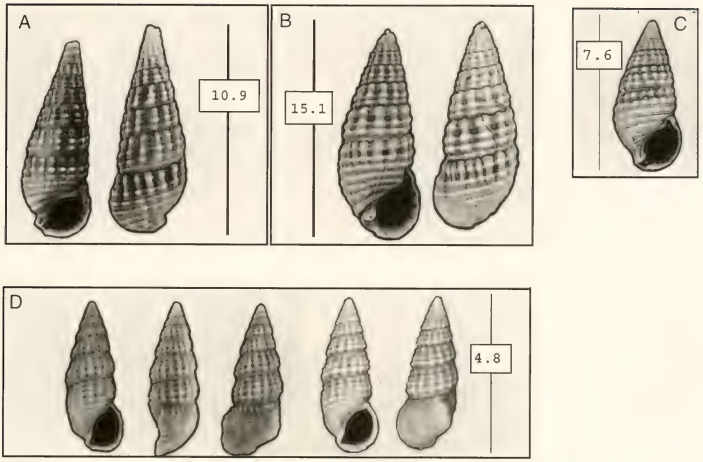
Diagnosis.—Strong vertical ribs that do not continue vertically from one whorl to the next. Coarse spiral ornament generates knobs on tops of ribs. Between the coarse spirals there are 3–4 fine spiral threads that do not create knobs.

Comparison.—Very similar to *Cerithium lutosum* Menke, 1828 (Text-fig. 50C), which has spiral rows of nodes without conspicuous vertical ribs, and has siphonal notches at both lower left and upper right corners of the aperture. Both shells commonly occur together around the edges of keys.

Name.—Batillaria minima (Gmelin, 1791).

Biofacies.—Most common in the Rocky Shore Biofacies. Commonly washed into Mud Flat and Playa samples. Rare in Northern, Central, *Cerithium, Tricolia* and Reef Tract Biofacies. Not found in *Lucina*, Grecian Rocks and Gulf Biofacies.

References.—Warmke and Abbott, 1961, p. 72, pl.



Text-figure 50.—Narrow, high-spired gastropods with siphonal notch at lower left of aperture. A, B. *Batillaria minima*. C. *Cerithium lutosum*. D. *Diastoma varia*.

13, fig. V; Morris, 1975, p. 148, pl. 43, fig. 9; Abbott, 1974, pp. 103–104, fig. 990; Emerson and Jacobson, 1976, pp. 82–83, pl. 20, fig. 19.

Diastoma varia
Text-figure 50D

AMOCO Taxon #.—2096

Diagnosis.—Small shells in which each whorl overhangs the whorl below, giving the spire a "Christmas Tree" profile. Siphonal notch present but not so pronounced as in *Batillaria*. Individual shells might or might not carry the large knob (varix) on the last whorl as in the figures above.

Comparison.—Compare with *Finella dubia* (Text-fig. 52A), described below.

Name.—Diastoma varia (Pfeiffer, 1840). Long known as *Bittium varium*.

Biofacies.—Found in all biofacies except Grecian Rocks. It is frequently a Dominant Taxon, especially in beach sediments. An Ubiquitous Taxon; never a Key Taxon.

References.—Warmke and Abbott, 1961, p. 73, pl. 13, fig. H, as *Bittium varium*; Morris, 1975, p. 150, pl. 43, fig. 14; Abbott, 1974, p. 107, fig. 1037; Emerson and Jacobson, 1976, p. 39, pl. 17, fig. 10.

NARROW, HIGH-SPIRED SHELLS WITH SIPHONAL NOTCHES AT LOWER LEFT AND UPPER RIGHT OF APERTURE

Cerithium muscarum
Text-figure 51A, B

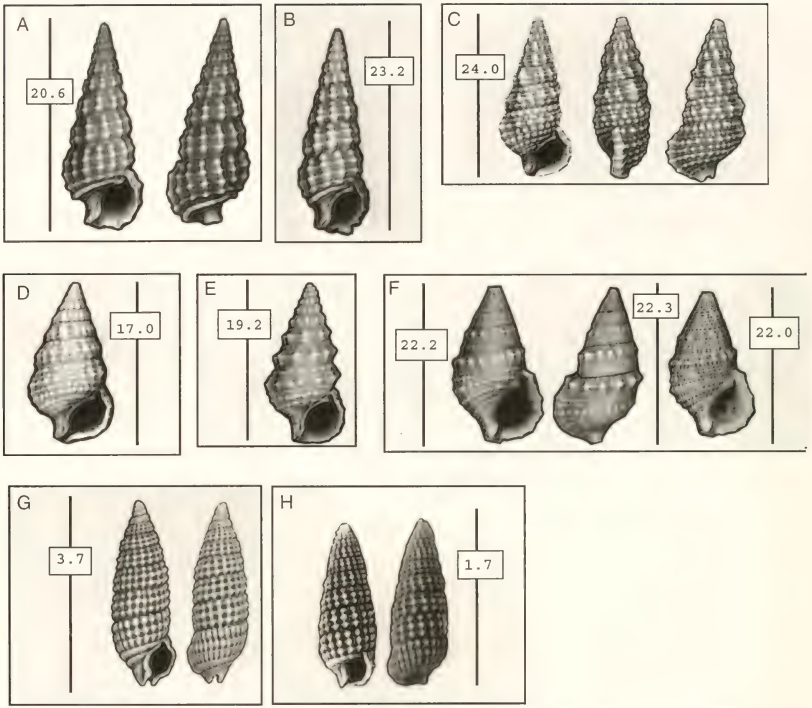
AMOCO Taxon #.—2091

Diagnosis.—Narrow shells about 25 mm high. Pleural angle (the angle formed by lines drawn from the apex of the shell, downward to points tangent to the curve of the last whorl on either side of the shell) 25°–28°. Ornament typically of strong axial (vertical) ribs that are not aligned from whorl to whorl. Fine spiral threads cross the ribs, and knobs tend to develop at their intersections.

This form intergrades with *Cerithium atratum* (Text-fig. 51C, D), described below, through shells in which the spiral threads become stronger and the axial ribs less pronounced.

Comparison.—Cerithium atratum has dominantly spiral ornamentation, becoming spiral rows of small knobs on the adult whorls.

Remarks.—The best way to separate the several forms of *Cerithium* is to check the pleural angle first. If it is narrow (25–28°), the shell is *C. muscarum*. If the pleural angle is larger, separation depends upon the ornamentation.



Text-figure 51.—Narrow, high-spired gastropods with siphonal notches at lower left and upper right of aperture. A, B. *Cerithium muscarum.* C, D. *Cerithium atratum.* E. *Cerithium algicola.* F. *Cerithium litteratum.* G, H. *Cerithiopsis greenii.*

Name.—Cerithium muscarum Say, 1832.

Biofacies.—Common in both Northern Subfacies and both Central Biofacies. Uncommon to rare in other biofacies, except Rocky Shore and Grecian Rocks, from which it was not recovered.

References.—Morris, 1975, p. 149, pl. 43, fig. 25; Abbott, 1974, p. 104, fig. 993; Rehder, 1981, p. 438, fig. 196; Abbott and Dance, 1982, p. 66, figured.

Cerithium atratum
Text-figure 51C, D

AMOCO Taxon #.—2093

Diagnosis.—Shells with a pleural angle of 35–40 degrees. Ornament of revolving rows of beads of differing sizes, with the largest beads at or just above the widest part of each whorl. Enlarged vertical ribs (varices) develop randomly over the shell, unlike the regular vertical ribs in *C. muscarum.*

Comparison.—The irregularly spaced varices are the distinctive characteristic of this taxon. There is a much less common variant of this shell that we distinguished as Amoco Taxon # 2094, *C. algicola* C. B. Adams, 1845 (Text-fig. 51E). In it, the knobs on the middle of each whorl are regularly spaced and sharp-pointed. Intergrading specimens between *C. algicola* and *C. atratum* exist.

Name.—Cerithium atratum (Born, 1778). Long known as *C. eburneum* Bruguière, 1792.

Biofacies.—Common in the *Cerithium* and *Tricolia* Biofacies. Uncommon in all marine biofacies except the Reef Tract.

References.—Warmke and Abbott, 1961, pp. 72–73, pl. 13, fig. N; Rehder, 1981, pp. 438–439, fig. 194; Abbott and Dance, 1982, p. 66, figured.

Cerithium litteratum
Text-figure 51F

AMOCO Taxon #.—2095

Diagnosis.—Shells with fine, slightly beaded revolving threads on the early whorls leaving the apex almost smooth. Enlarged nodes present at the top of the last two or three whorls in mature specimens. Apex of shell flat.

Comparison.—No other shell has the smooth apical whorls and flat apex of this taxon.

Name.—Cerithium litteratum (Born, 1778).

Biofacies.—Moderately common in Reef Tract and Grecian Rocks Biofacies. Uncommon in *Cerithium* and *Tricolia* Biofacies. Rare in Central Exterior. Not recovered elsewhere.

References.—Warmke and Abbott, 1961, p. 72, pl. 13, fig. O; Morris, 1975, p. 149, pl. 43, fig. 26 (misspelled); Abbott, 1974, p. 104, fig. 994; Rehder, 1981, pp. 437–438, fig. 197; Abbott and Dance, 1982, p. 65, figured.

Cerithiopsis greenii
Text-figure 51G, H

AMOCO Taxon #.—2098

Diagnosis.—Shells tall, narrow, and ovoid when mature. Ornament on each whorl comprises three spiral rows of beads connected by fine axial and spiral threads. Can reach a height of 6 mm.

Comparison.—The combination of the ovoid shape and the three rows of beads connected only by threads (not strong ribs) is distinctive.

Name.—Cerithiopsis greenii (C. B. Adams, 1839).

Biofacies.—Moderately common in the Grecian Rocks Biofacies. Uncommon to rare in all other Biofacies.

References.—Morris, 1975, p. 151, pl. 43, fig. 19, as *C. greeni*; Abbott, 1974, pp. 108–109, fig. 1048, as *C. greeni*; Emerson and Jacobson, 1976, p. 79, pl. 19, fig. 23, as *C. greeni*; Rehder, 1981, p. 443, fig. 187.

APERTURE WITHOUT SIPHONAL NOTCHES

Finella dubia
Text-figure 52A, D

AMOCO Taxon #.—3042

Diagnosis.—Smaller than *Diastoma.* Whorls have a rounded outline (periphery) with ribs and spiral ornament of about equal strength (cancellate).

Comparison.—Never shows the "Christmas tree" profile that distinguishes *Diastoma.*

Name.—Finella dubia (d'Orbigny, 1840).

Biofacies.—Common in *Tricolia,* Reef Tract, and Grecian Rocks Biofacies. Uncommon in both Central. *Cerithium* and *Lucina* faunas. Rare in other marine biofacies except Rocky Shore, where it was not found.

References.—Abbott, 1974, p. 108, fig. 1039.

Cerithidea costata
Text-figure 52B, C

AMOCO Taxon #.—2114

Diagnosis.—Shells tall, with multiribbed ornament. Adult shells with flared aperture. Adults up to 50 mm high or as small as 10 mm, as discussed in the text.

Name.—Cerithidea costata (da Costa, 1778).

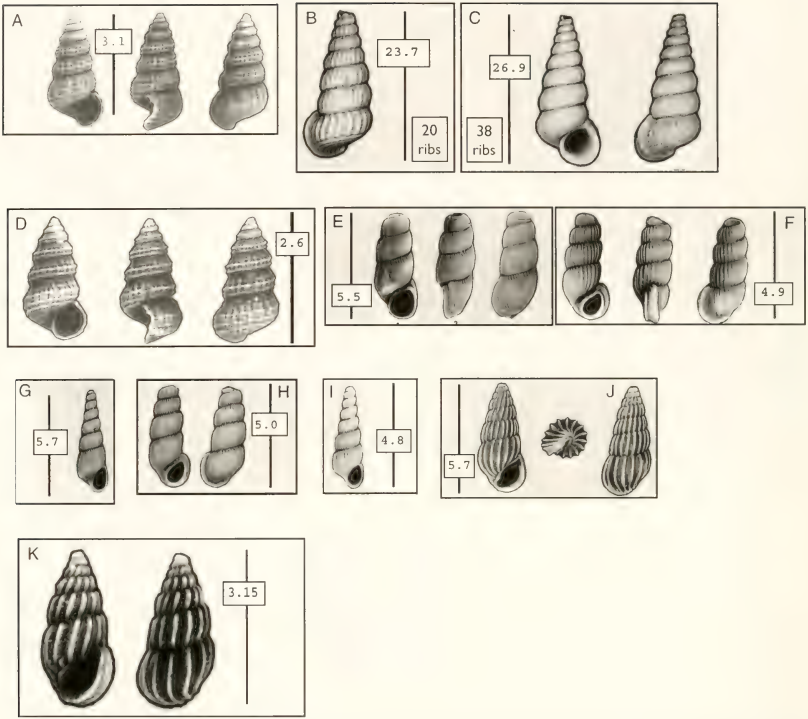
Biofacies.—Most common on playas. Common in Everglades, Mud Flat and Northern *Anomalocardia.* Less common in Northern *Parastarte.* Rare in both Central Interior and Exterior, Gulf, *Lucina, Cerithium* and Reef Tract. Not seen from Rocky Shore, *Tricolia* or Grecian Rocks faunas.

Remarks.—Two "species" have been recognized: *C. scalariformis* (Say, 1825) (Text-fig. 52B) (ladder-shaped) and *C. costata* (costate or ribbed) (Text-fig. 52C). The former name is used for shells with distinct vertical ribbing. The latter, for shells in which the last adult (body) whorl is essentially smooth or bears only narrow threads.

The shell shown in Text-figure 52B is typical "*scalariformis*" while that shown in Text-figure 52C is the non-costate form called "*costata*". It is clear from the many hundreds of these shells seen during this study that the two so-called "species" are end members of a continuous series. Shells in which the ribbing is distinct bear from just under 20 ribs per whorl to about 25–30 ribs. The rib count for the "smooth" shells begins in the middle thirties and ranges above 40 ribs per whorl. Intermediate shells can be placed in one or the other "species" depending on how sharp your eyes are, how well preserved the shell surface is, and whether the shell has been coated to enhance the appearance of the ribs. The end members are distinctive, but they are connected by an unbroken series of intermediate forms.

Because there is no objective way to break this series of rib counts, we have used only the older name "*costata*" for this taxon.

References.—((c) = "*costata*"; (s) = "*scalariformis*") Warmke and Abbott, 1961, p. 71, pl. 13, fig. S (c); Morris, 1975, p. 147, pl. 43, fig. 8 (c); Morris, 1975, p. 147, pl. 43, fig. 7 (s); Abbott, 1974, pp. 103–104, fig. 980 (c); Abbott, 1974, p. 104, fig. 986 (s); Emerson and Jacobson, 1976, p. 82, pl. 20, fig. 17 (c);



Text-figure 52.—Gastropods with apertures lacking siphonal notches. A, D. *Finella dubia.* B, C. *Cerithidea costata.* E. *Truncatella pulchella.* F. *Truncatella bilabiata.* G. Effaced juvenile of *Truncatella.* H. Effaced *Truncatella bilabiata.* I. Ribbed juvenile of *Truncatella.* J. *Rissoina bryerea.* K. *Rissoina fischeri.*

Emerson and Jacobson, 1976, p. 82, pl. 20, fig. 18 (s); Rehder, 1981, p. 434, fig. 127 (s); Rehder, 1981, p. 435, fig. 124, (c)

Truncatella spp.

Text-figure 52E–I

AMOCO Taxon #.—2119 = *pulchella* (Text-fig. 52E); 2120 = *bilabiata* (Text-fig. 52F); 2483 = both taxa combined.

Diagnosis.—Shell thin, fragile. The two individual taxa, shown above, are discriminated by the shape of the aperture, which is simple in *T. pulchella* but bears a strong varix just behind the lip of the shell in *T. bilabiata.* In most specimens the surface of *pulchella* is effaced and well-ribbed in *bilabiata,* but as the effaced specimens in Text-figures 52G, H show that some bilabiate shells are also effaced so it is impossible to use surface ornament to separate the taxa.

Comparison.—The blunted apex, rather open coiling and apertural structures are distinctive in the adult shells. No other adult shell looks like the juvenile portion of *Truncatella.*

Name.—*Truncatella pulchella* Pfeiffer, 1839. *Truncatella bilabiata* Pfeiffer, 1840.

Biofacies.—A nonmarine shell, it is Dominant on mud flats and common in the Everglades and Playa Biofacies. It is buoyant enough to have drifted as isolated individuals into all except the Gulf, Rocky Shore and Grecian Rocks Biofacies.

Remarks.—Truncatella begins its growth with a high-spired shell that is ultimately shed, leaving a blunt apical callus on the adult shell. Well-ribbed juvenile shells (Text-fig. 52I) can be assigned with some confidence to *bilabiata,* but effaced juveniles, while more commonly from *pulchella* can also be from the effaced forms of *bilabiata.* In our counting for quantitative samples, only adult segments were counted to avoid duplication, but the number of juvenile segments was also noted. Because of their fragile nature, juveniles were never more abundant than adult shells.

Field samples usually contain many more specimens that lack the distinctive apertures than those that retain them. Had we counted only the specimens preserving the apertural structures, *Truncatella* would have been badly undercounted. Therefore, in our quantitative analyses both types were included under the Amoco Taxon # 2483. However, the counts of the separate taxa are given in the sample analysis sheets, and the specimens were separated for storage.

My opinion, apparently shared by others, is that these two "species" are actually only variants of a single biological entity.

References.—Pilsbry, 1948, pp. 1070–1072, fig. 572; Warmke and Abbott, 1961, p. 55, pl. 10, fig. B; Abbott, 1974, p. 80, fig. 718; Rehder, 1981, pp. 417–418, fig. 224 (includes both forms in *T. pulchella*) (all of the above references used *T. pulchella*); Pilsbry, 1948, pp. 1069–1070, fig. 570–1, 3, 6; fig 571a-b (as *T. bilabiata*); Warmke and Abbott, 1961, p. 55, pl. 10, fig. A (as *T. pulchella* form *bilabiata*).

Rissoina bryerea
Text-figure 52J

AMOCO Taxon #.—2117

Diagnosis.—Sturdy, thick shell. Aperture hemiovate. 16–20 strong vertical ribs; no spiral threads. Sutures between whorls distinct but not deeply incised.

Comparison.—Similar to *R. fischeri,* described below, but that form has fewer ribs and more deeply incised sutures.

Name.—Rissoina bryerea (Montagu, 1803).

Biofacies.—Common in Central Exterior, *Lucina* and Grecian Rocks Biofacies. Less common in all other biofacies except Rocky Shore where it has not been found.

References.—Warmke and Abbott, 1961, p. 56, pl. 10, fig. M; Morris, 1975, p. 135, pl. 39, fig. 1; Abbott, 1974, p. 76, fig. 673; Emerson and Jacobson, 1976, p. 60, pl. 19, fig. 9.

Rissoina fischeri
Text-figure 52K

AMOCO Taxon #.—26689

Diagnosis.—Sturdy, thick shell. Aperture hemiovate. 10–15 strong curving ribs; no spiral threads. Whorls convex; sutures deeply incised.

Comparison.—Similar to *R. bryerea,* described above, but with fewer ribs and deeply incised sutures that make the top of each whorl appear almost horizontal.

Name.—Rissoina fischeri Desjardin, 1949.

Biofacies.—Common only in the Grecian Rocks Biofacies. Uncommon in the Reef Tract Biofacies. Rare in Central, *Cerithium* and *Tricolia* Biofacies. Not found elsewhere.

References.—Warmke and Abbott, 1961, p. 56, pl. 10, fig. N; Morris, 1975, p. 135, pl. 39, fig. 4;

TROCHOIDAL SHELLS WITH LARGE BODY WHORLS AND SMOOTH ADULT SURFACES

Littorina ziczac
Text-figure 53A

AMOCO Taxon #.—3032

Diagnosis.—Helically coiled shell with open semiovate aperture. No siphonal notches. Adult shell is smooth, but the juvenile portion bears fine revolving threads. The color markings are characteristic, if preserved.

Comparison.—Similar to the other shells in this section in gross shape, but much larger. Some other shells have structures on the inner side of the aperture.

Name.—Littorina ziczac (Gmelin, 1791).

Biofacies.—Found only in the Rocky Shore assemblage.

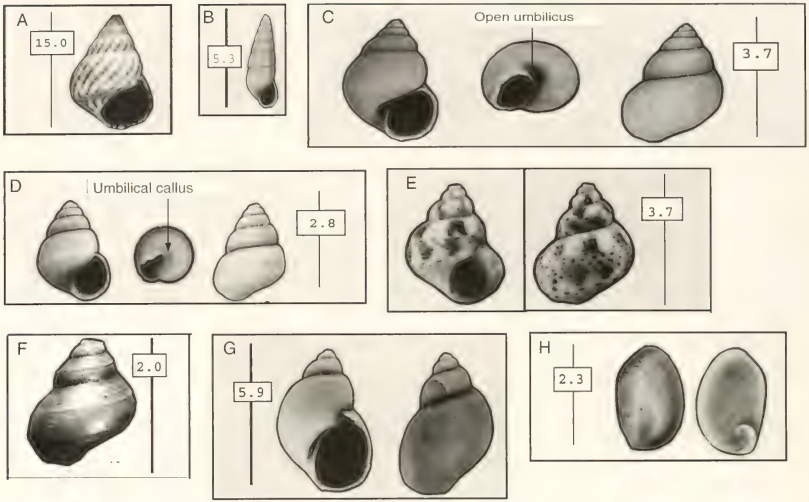
References.—Morris, 1975, p. 132, pl. 40, fig. 8; Abbott, 1974, p. 68, pl. 3, fig. 556; Emerson and Jacobson, 1976, p. 58, pl. 19, fig. 4; Rehder, 1981, p. 404, fig. 242.

Hydrobia totteni
Text-figure 53C

AMOCO Taxon #.—2605

Diagnosis.—Whorl profile convex, with well-incised sutures. Surface entirely smooth, save for growth lines. No apertural structures. The umbilicus is open, without callus.

Comparison.—This shell is essentially identical with that described immediately following except for its open umbilicus. It resembles some smooth forms of *Odostomia* (Text-fig. 53B), but they have less convex whorls,



Text-figure 53.—Trochoidal gastropods with large body whorls and smooth adult surfaces. A. *Littorina ziczac*. B. *Odostomia laevigata*. C. *Hydrobia totteni*. D. Gastropod 2482. E, F, G. *Tricolia affinis*. H. Operculum of *T. affinis*.

more whorls and narrower shells. There is also a small foldlike structure on the axis (invisible in the photo).

Name.—Hydrobia totteni Morrison, 1954.

Biofacies.—The Key Taxon in the Everglades fauna and commonly Dominant in the Northern *Anomalocardia* Subfacies. Can be abundant on Playas in the northern Bay, washed in by storms. Found rarely in all other biofacies, except Gulf and Reef Tract, where it has floated in because of its small size and buoyancy.

References.—Smith, 1951, p. 97, pl. 37, fig. 12; pl. 71, fig. 17 as *Hydrobia minuta* (Totten, 1834). Thompson, 1968, p. 35 et seq. (regards *Hydrobia* as a European form. Taxon 2605 apparently includes all four genera in his "*Hydrobia* Tribe"); Morris, 1973, p. 134, pl. 39, fig. 23 (a taller form, as *Hydrobia minuta*).

Remarks.—Among taxonomists dealing with living mollusks, taxa are often separated on the basis of differences in the soft parts, such as genitalia, and the shell is not considered or is deemphasized. This approach is impossible for studies confined to the shells alone, so we have appropriated the name "*totteni*". Readers should realize that the nomenclature used here might conflict with that used for living animals.

Gastropod 2482
Text-figure 53D

AMOCO Taxon #.—2482

Diagnosis.—Whorl profile convex, with well-incised sutures. Surface entirely smooth, save for growth lines. No apertural structures. The umbilicus is concealed by a smooth callus.

Comparison.—This shell is essentially identical to *Hydrobia totteni* except for its umbilical callus.

Name.—Unknown.

Biofacies.—Second in abundance to *Hydrobia* in the Everglades Biofacies and second to *Truncatella* on mud flats. A minor element in the Northern *Anomalocardia* Subfacies and on playas. Rare in both Central Biofacies and in the *Cerithium* Biofacies. Not found elsewhere.

Tricolia affinis
Text-figure 53E, F, G

AMOCO Taxon #.—2013

Diagnosis.—Small trochoid shells, very similar in overall shape to the two preceding taxa, but with a much stouter shell. Shells normally bear red to brown

dots and splotches (Text-fig. 53E). The first three whorls at the apex of the shell normally bear spiral threads that can appear to cause a shoulder on the third whorl (Text-fig. 53F); thereafter, all whorls are smooth. The aperture of the adult whorl reflects the contour of the whorl. Where the shell is more tightly coiled the aperture is subcircular (Text-fig. 53E). In about 5% of the individuals the coiling is looser (Text-fig. 53G) so that the whorl profile is arcuate, and the aperture is vertically elongated.

Comparison.—No other shells of this general shape have appeared in our samples, and significant comparisons among these taxa have been desribed in the diagnoses.

Name.—Tricolia affinis (C. B. Adams, 1850).

Remarks.—Three names have been applied to these shells. Those with rounded adult whorls and a subcircular aperture have been called *T. thalassicola* Robertson, 1958. The elongated shells have been named *T. affinis*. Shouldered shells have been given the name *T. bella* (M. Smith, 1937). The threads that cause shouldering are an ontogenetic feature, developed on the juvenile portion of both circular or elongate shells. Because juvenile threads can be seen on all shells that are sufficiently well preserved, they do not serve to discriminate a separate taxon. The typical *Tricolia* aperture is subcircular, and the most elongate shells (Text-fig. 53G) are distinguishable from them. But the two shapes are joined by intermediate stages forming a continuum that reflects only the degree of tightness in the shell's coiling. In any sufficiently large sample all three of the named "species" will appear. Most shells will have subcircular apertures (*thalassicola*), and a few of these will be shouldered by thickening of the juvenile threads (*bella*). Elongated shells (*affinis*) develop about 5% of the time and so are uncommon. Rarest of all are shouldered elongate shells that have no formal name. From this array the oldest (first published) name must be selected as the valid designation, and that is *affinis*.

Biofacies.—The second most common shell in the *Tricolia* Biofacies after *Caecum nitidum*. Also common in the *Cerithium*, Reef Tract, and Grecian Rocks Biofacies. Uncommon in the Gulf Biofacies and rare in other biofacies, except the Northern and Everglades Biofacies where it has not been found.

References.—The authors listed here give multiple names to this shell, all of which, except *affinis*, I believe are unnecessary: Warmke and Abbott, 1961, pp. 48–49; Morris, 1975, p. 126; Abbott, 1974, pp. 61–62; Emerson and Jacobson, pp. 47–48; Rehder, 1981, pp. 395–396.

Operculum of *Tricolia affinis*
Text-figure 53H

AMOCO Taxon #.—3177

Diagnosis.—Minute calcareous operculum with a slightly elevated spire internally. The exterior face is gently convex with a small pit opposite the internal spire. The exterior surface is marked by delicate radial striations.

Remarks.—This is the only operculum that is common enough to be a significant item in quantitative samples (see Table 6). It is sometimes abundant enough to be seen even in field samples, so it is included here.

Comparison.—There are other minute opercula, but none approaches this in abundance. The somewhat angular shape, the internal spire and the exterior striations are the distinctive features.

Biofacies.—Theoretically the operculum has the same distribution as its host shell, but it is much less abundant than the shell itself so it is rare except where *Tricolia* is abundant.

TROCHOID SHELLS SHAPED AS ABOVE WITH ADULT SURFACES ORNAMENTED

Alvania auberiana
Text-figure 54A

AMOCO Taxon #.—3281

Diagnosis.—Shells 2–3 mm high. Aperture subcircular. No siphonal notch. First two (nuclear) whorls smooth and clearly visible. Postnuclear whorls strongly cancellate, but on the base of the whorl the vertical (axial) ribbing dies out and the spiral ribs become dominant.

Comparison.—Bears some resemblance to *Finella dubia*, described above, but that shell has much finer ornament, more whorls and four to five distinctive, angulate nuclear whorls.

Name.—Alvania auberiana (d'Orbigny, 1842).

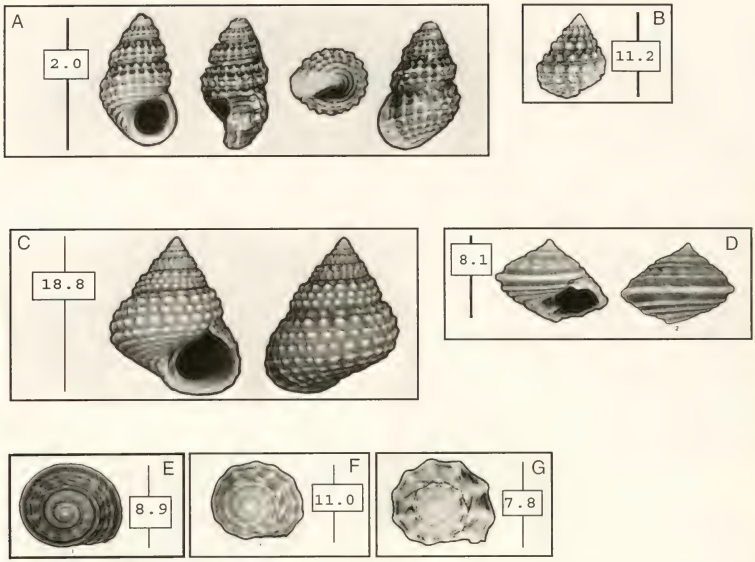
Biofacies.—Moderately common in the Grecian Rock and Reef Tract Biofacies. Uncommon in the *Cerithium* and *Tricolia* Biofacies. Rare in the Central and Gulf Biofacies.

References.—Warmke and Abbott, 1961, p. 58, pl. 10, fig. K; Morris, 1975, p. 136, pl. 38, fig. 14; Abbott, 1974, p. 71, fig. 586.

Tectarius muricatus
Text-figure 54C

AMOCO Taxon #.—2073

Diagnosis.—Trochoid shells up to 20 mm high with rows of regularly spaced, rounded nodes over the entire surface. The aperture is subcircular, without notches, reflecting the rounded profile of each whorl.



Text-figure 54.—Trochoidal gastropods with large body whorls and ornamented adult surfaces. A. *Alvania auberiana*. B. *Nodilittorina* sp. C. *Tectarius muricatus*. D. *Modulus modulus*. E. *Modulus modulus* (smooth periphery). F. *Modulus modulus* (intermediate periphery). G. *Modulus modulus* (angulated periphery).

Comparison.—The regularity of the nodes sets *Tectarius* apart from other periwinkles with which it is commonly found. The associated shells have spinose ornament or nodes of various sizes as, *e.g.*, in *Nodilittorina* sp. (Text-fig. 54B).

Name.—*Tectarius muricatus* (Linnaeus, 1758).

Biofacies.—Key taxon for the Rocky Shore Biofacies, where is lives on the rocks above the splash zone in great numbers. Isolated specimens have been found in a *Lucina* assemblage and on a mud flat, where they were doubtless carried by a storm.

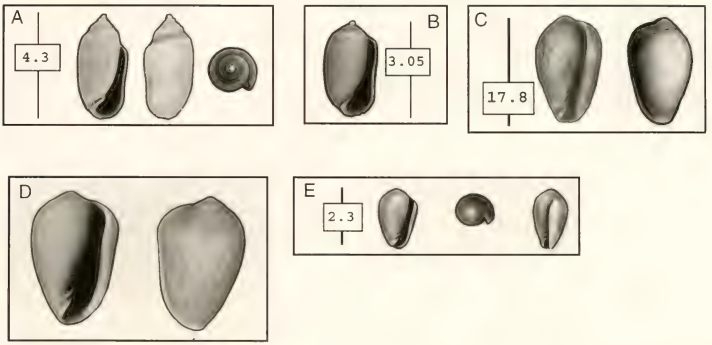
References.—Warmke and Abbott, 1961, pp. 54–55, pl. 9, fig. G; Morris, 1975, p. 133, pl. 40, fig. 11; Abbott, 1974, p. 70, fig. 571; Emerson and Jacobson, 1976, pp. 58–59, pl. 19, fig. 6; Abbott and Dance, 1981, p. 58, figured.

Modulus modulus
Text-figure 54D–G

AMOCO Taxon #.—2009

Diagnosis.—Shell rhombic when viewed from the apertural or abapertural side (Text-fig. 54D). Each whorl edged by a single thick cord that makes each whorl distinct in apical view. The base, below the marginal cord bears half a dozen spiral cords. Ornamentation on the spire is variable. Most commonly it bears somewhat discontinuous spiral cords crossing 10–15 low, radially arranged ribs (the smooth periphery) (Text-fig. 54E). In some intermediate shells the radial ribs become more prominent and cause the periphery of the shell to become "bumpy" in apical view (Text-fig. 54F). In some shells the radial ribs become the dominant feature and the spiral cords are much reduced. These shells have a strongly angulated periphery (Text-fig. 54G). This progression is illustrated in Text-figures 54E, F, and G.

Remarks.—During the first 13 years of this study the two end members in the sequence shown above were recorded separately, but there was the ever-present problem of assigning intermediate shells to one taxon or the other. In 1977 all records of *Modulus* were mapped in hopes that the distribution of the two forms



Text-figure 55.—Vertically subcylindrical gastropods with vertically elongate apertures and apex visible. A, B. *Retusa candei*. C. *Marginella carnea*. D. *Marginella apicina*. E. *Marginella lavalleana*.

would show some geographic or environmental differentiation. It did not, and all specimens were treated thereafter as one taxon.

Several of the compendia of seashells show a form of *Modulus* in which there are heavy radial ribs on a convex spire, but in which the periphery is not angulated as in the Florida Bay shells. No specimens of this form of shell have appeared in our samples.

Comparison.—No other comparable rhombic, heavily corded shell appeared in our sampling.

Name.—*Modulus modulus* (Linnaeus, 1758).

Biofacies.—This is one of the Ubiquitous Taxa, found in all except the Rocky Shore Biofacies. In a few samples it is the Dominant Taxon, but because it is so common and widespread it is never a Key Taxon.

References.—Warmke and Abbott, 1961, pp. 70–71, pl. 11, fig. J; Abbott, 1974, p. 102, fig. 976.

VERTICALLY SUBCYLINDRICAL SHELLS WITH VERTICALLY ELONGATE APERTURES AND APEX VISIBLE

Retusa candei
Text-figure 55A, B

AMOCO Taxon #.—2040

Diagnosis.—Small subcylindrical shells. Surface smooth except for minute growth lines. Aperture narrow, widening at the base; it occupies 70–85% of the shell height depending on the height of the spire, which is variable.

Comparison.—Differs from some Marginellidae with similar narrow apertures in having subparallel sides. The comparable marginellids taper to a narrow base, *e.g.*, as in the *Marginella* shown next (Text-fig. 55C–E).

Name.—*Retusa candei* (d'Orbigny, 1841).

Biofacies.—Most common in the Northern Biofacies. Uncommon in all others, except the Rocky Shore Biofacies, where it was not found.

References.—Warmke and Abbott, 1961, p. 143, pl. 27, fig. G; Morris, 1975, p. 267, pl. 73, fig. 2; Abbott, 1974, p. 313, fig. 3919; Emerson and Jacobson, 1976, p. 182, pl. 24, fig. 26.

Marginella carnea
Text-figure 55C

AMOCO Taxon #.—3035

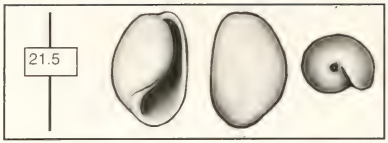
Diagnosis.—Shell low spired, elongate tapering toward the base. Heavy callus deposit on outer lip of the aperture and extending up to the apex, which can be partly hidden.

Comparison.—Discrimination of marginellid shells is difficult, and a careful study of the references below is advised. Two shells that are more common than *M. carnea* are *M. apicina* Menke, 1828 (Text-fig. 55D) and *M. lavalleana* d'Orbigny, 1842 (Text-fig. 55E), both of which are smaller than *M. carnea*.

Name.—*Marginella* (*Prunum*) *carnea* Storer, 1837.

Biofacies.—Most common in the Grecian Rocks fauna, but not Dominant. Uncommon in the Reef Tract Biofacies. Rare in the *Cerithium* and *Tricolia* Biofacies. Not found elsewhere.

References.—Morris, 1975, p. 233, pl. 64, fig. 10; Abbott, 1974, p. 250, pl. 11, fig. 2723; Rehder, 1981,



Text-figure 56.—Vertically ovate gastropod with depressed (hyperstrophic) apex: *Bulla striata.*

p. 598, fig. 329; Abbott and Dance, 1982, p. 235, figured.

VERTICALLY OVATE SHELLS WITH DEPRESSED (HYPERSTROPHIC) APEX

Bulla striata
Text-figure 56

AMOCO Taxon #.—2032

Diagnosis.—Large vertically ovate shells with an apical depression (umbilicus), an aperture that flares toward the base and a tendency to narrow apically.

Name.—*Bulla striata* Bruguière, 1792.

Biofacies.—*Bulla* is one of the Ubiquitous Taxa, present in all biofacies except for Rocky Shore and Grecian Rocks. It is most common in the *Cerithium* and Gulf Biofacies and moderately common in all others.

Remarks.—The names *B. striata* and *B. occidentalis* A. Adams, 1850, have both been widely applied to this form. The older name *striata* should be used.

References.—Warmke and Abbott, 1961, p. 141, pl. 27, fig. E; Morris, 1975, p. 264, pl. 72, fig. 22; Abbott, 1974, p. 319, pl. 10, fig. 4000; Rehder, 1981, p. 641, fig. 365; Abbott and Dance, 1982, p. 279, figured.

MINUTE, ARCUATE SHELLS

Caecum pulchellum
Text-figure 57A, B

AMOCO Taxon #.—2079

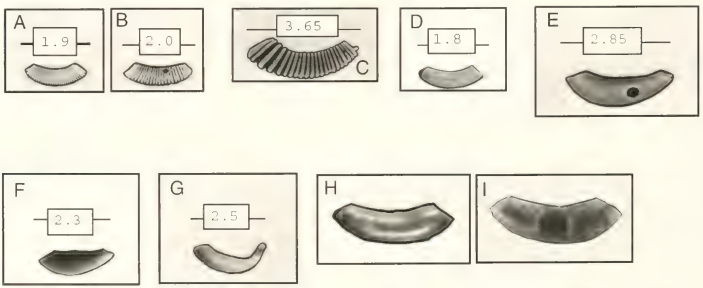
Diagnosis.—*Caecum* with regular, annular rings. The rings and the spaces between them are about equal in width. About 25 rings on a shell. There is no heavy annular ring at the mouth of the shell.

Remarks.—There is a wide variety of caecids in Florida Bay and especially on the reef tract. Ten forms were separated for use in this study, but there are apparently others in the sediments. Of the ten types, only the three noted here are sufficiently common to be Dominant or Key Taxa. The caecids can be quickly divided into two groups: (A) those with surface ornament, and (B) those with smooth shells. The ornamented shells are separable into a group bearing only annular rings and a more complex group bearing principally longitudinal ornament, with or without annular rings. None of the longitudinal group is common enough to be of significance in biofacies separation.

Comparison.—There are two other taxa with dominant annular ornament: *Caecum* 2168 (Text-fig. 57C) has a heavier shell, is longer, and bears three or four heavy apertural rings. *Caecum* 3279 (Text-fig. 57D) lacks apertural rings and has many more, finer annular rings than *C. pulchellum.*

Name.—*Caecum pulchellum* Stimpson, 1851.

Biofacies.—Found in all biofacies except Rocky Shore. A Key Taxon in the Grecian Rocks Biofacies. Abundant in the Reef Tract, *Tricolia* and both Central Biofacies. Common in the *Lucina* and Gulf faunas. Present generally elsewhere but uncommon near the Everglades.



Text-figure 57.—Gastropods with minute, arcuate shells. A, B. *Caecum pulchellum.* C. *Caecum* 2168. D. *Caecum* 3279. E, F, G. *Caecum nitidum.* H. *Caecum cornucopiae* (normal adult). I. *Caecum cornucopiae* (drilled adult).

References.—Warmke and Abbott, 1961, p. 67, text fig. 15a; Morris, 1975, p. 139, pl. 41, fig. 7; Abbott, 1974, p. 91, fig. 866; Rehder, 1981, p. 420, fig. 104; Emerson and Jacobson, p. 70, pl. 20, fig. 4.

Caecum nitidum
Text-figure 57E–G

AMOCO Taxon #.—2080

Diagnosis.—Smooth caecids with an inflated arcuate ventral profile (Text-fig. 57E) and, in many specimens, with a complementary hump on the dorsal side (Text-fig. 57F).

Remarks.—The caecid shell consists of three segments, the earliest two of which drop off as the animal grows. In a small minority of specimens the second (middle) section does not break free; this usually prevents the adult segment from reaching maturity. Identification of the separated juvenile and adolescent segments with the adult shells is a difficult and painstaking task so the earlier segments are not illustrated here except for this taxon in which the juvenile segment has a distinctive cow's horn shape (Text-fig. 57G).

This group of smooth caecids is referred by some authors to the genus or subgenus *Meioceras*. Thus, both *Meioceras nitidum* and *Caecum* (*Meioceras*) *nitidum* can be found in different publications.

Comparison.—The only shell likely to be confused with *C. nitidum* is the next to be described, *C. cornucopiae*.

Name.—*Caecum nitidum* Stimpson, 1851.

Biofacies.—The Key Taxon in laboratory samples from the *Tricolia* Biofacies and abundant in adjacent *Cerithium* and Reef Tract Bifoacies. A minor component of all other biofacies except the Rocky Shore, where it has not been seen.

References.—Warmke and Abbott, 1961, p. 70, text-fig. 15c.; Abbott, 1974, p. 94, fig. 895; Emerson and Jacobson, p. 71, pl. 19, fig. 20.

Caecum cornucopiae
Text-figure 57H–I

AMOCO Taxon #.—3280

Diagnosis.—Smooth shell with regularly arcuate ventral and dorsal profiles. In some specimens the ventral profile is flattened in the center.

Comparison.—Lacks the bulbous venter or the dorsal hump of *C. nitidum*.

Name.—*Caecum cornucopiae* (Carpenter, 1858).

Remarks.—This shell has also been reported under the name *C. nebulosum* (Rehder, 1943), but Abbott (cited below) has suppressed that name in favor of Stimpson's, which is older.

Despite the apparent similarity of *C. nitidum* and *C. cornucopiae*, their separation is critical because the former is characteristic of the *Tricolia* Biofacies, while the latter is the Key Taxon of the Reef Tract Biofacies.

Biofacies.—The Key Taxon of the Reef Tract Biofacies. Moderately common in the *Tricolia* and Grecian Rocks Biofacies. Uncommon in the *Cerithium, Lucina,* Central and Gulf Biofacies. Not found elsewhere.

References.—Warmke and Abbott, 1961, pp. 67, 70, text-fig. 15d (as *nebulosum*); Abbott, 1974, p. 94, not figured (synonymizes *nebulosum*).

SHELL IRREGULARLY UNCOILED

Vermicularia spirata
Text-figure 58A–E

AMOCO Taxon #.—2102

Diagnosis.—Initial stages show regular coiling in a high-spired narrow shell. After 1–6 whorls the shell becomes highly irregular.

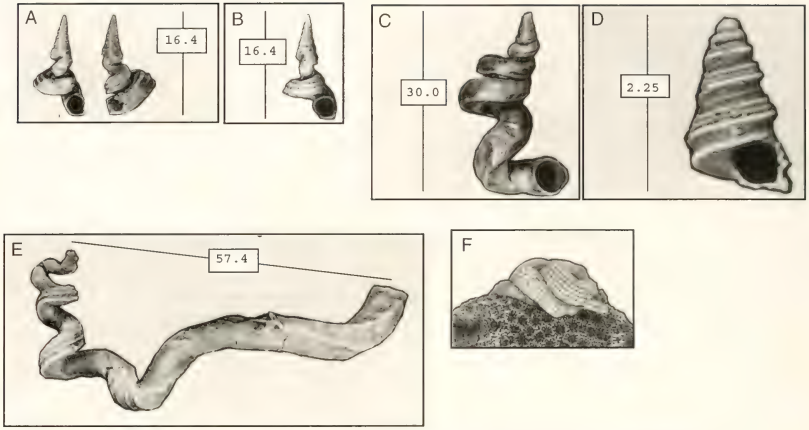
Remarks.—The shells in Text-figures 58A and B show a similar tendency for the first growth after the regular initial whorls to be almost straight downward, but the coiling in Text-figure 58C is simply looser, with no downard direction. The long fragment (Text-fig. 58E) has lost almost all of the initial regular whorls but is a good illustration of the irregular shape of a large adult shell.

The name *V. knorri* (Deshayes, 1843), has been used for small shells having a white apex and one spiral cord. *V. fargoi* Olsson, 1951, has been proposed for shells 0.75 inch (1.9 cm) high with two or three cords. The white apices occur randomly and can be found on as little of the shell as the protoconch alone (Text-fig. 58D) or extending to the third or fourth whorl (Text-fig. 58B). The presence or absence of this feature or its extent on the shell itself is too variable a characteristic to serve as a reliable basis for discrimination.

The number of spiral cords used in the separation of *V. knorri* and *V. fargoi* depends upon the available space on the shell. Early whorls are not wide enough to accommodate the three cords normally present in the adult. The apical fragment shown in Text-figure 58D bears an initial white protoconch (nuclear whorl) followed by a dark first postnuclear whorl bearing a single spiral cord. The second whorl has a thin central cord bordered by two heavier cords. The third whorl shows the adult pattern of three cords, with the lowest cord heavier than the two above it.

Name.—*Vermicularia spirata* (Philippi, 1836).

Comparison.—*Petaloconchus* sp. (Text-fig. 58F) is another uncoiled form, but it has no regularly coiled initial phase and forms tangled, attached masses rather than the erratic free shell of *Vermicularia*.



Text-figure 58. Gastropods with irregularly uncoiled shells. A-E. *Vermicularia spirata*. F. *Petaloconchus* sp.

Biofacies.—A Key Taxon in the *Cerithium* Biofacies, *Vermicularia* is common in *Tricolia* samples, also. It is uncommon in Gulf and *Lucina* samples. Specimens have been found occasionally in all other biofacies except the Northern *Anomalocardia* Subfacies.

References.—(f = *fargoi*; k = *knorri*; s = *spirata*) Warmke and Abbott, 1961, p. 64, pl. 12, fig. C (k, s); Morris, 1975, pp. 141–142, pl. 41, figs. 15–17 (f, k, s); Abbott, 1974, p. 96, figs. 918–920 (f, k, s); Rehder, 1981, p. 425, fig. 95 (s); Emerson and Jacobson, 1976, pp. 73–74, pl. 6, fig 2 (s); pl. 20, fig. 6 (k); Abbott and Dance, 1983, p. 61, figured (s).

CUP-SHAPED WITH AN INTERNAL SHELF

Crepidula fornicata
Text-figure 59A–G

AMOCO Taxon #.—2001

Diagnosis.—Generally smooth, open shells of less than one whorl, characterized by a platform developed in the umbonal area.

Remarks.—These shells are attached throughout life, and the surfaces to which they fasten themselves determines to a large extent the ultimate shape of each shell. Shells attached to a relatively flat surface tend to become broad and low-profiled, as in Text-figure 59A. More typical of the Florida Bay shells are those in Text-figures 59B and C, which have been free to grow upward but have been confined to a relatively narrow surface of attachment.

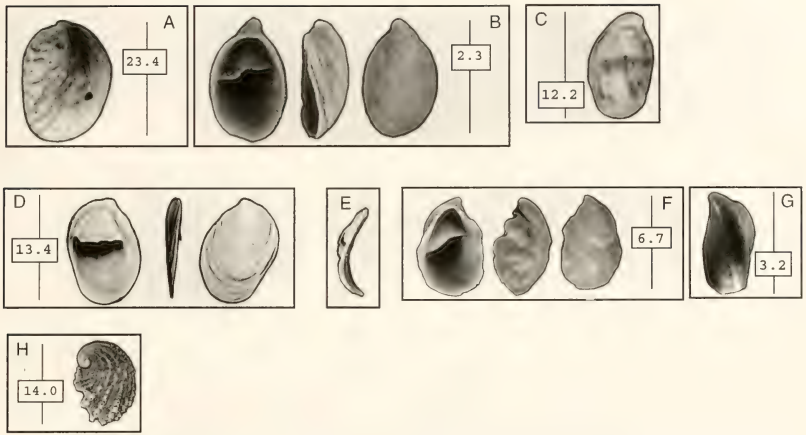
Where a *Crepidula* has settled on a concave surface such as inside the mouth of a large dead shell or inside a bottle, the profile of the shell is reversed and becomes concavo-convex (Text-figs. 59D, E) instead of convexi-concave. The shell in Text-figure 59E is 6.1 mm long, but it is broken at the anterior end so its original length is unknown.

In 1978, I found a dead *Fasciolaria* shell six inches (15.2 cm) high covered with *Crepidula*. The shells on the upper whorls near the apex of the shell were narrow and strongly convex, as in Text-figures 59B and C. Shells on the body whorl were broad and low, as in Text-figure 59A. Inside the aperture, where the curvature was reversed, all of the *Crepidula* were concave, as in Text-figure 59E.

Text-figures 59F and G are of two shells distorted by their substrata. The shell in Text-figure 59F was attached to a heavily ribbed shell (possibly an oyster) which deflected the margin. The shell in Text-figure 59G was apparently distorted by growing attached to a surface that was not straight.

The varying shapes recognizable among these shells has led to the designation of various "species":

- *C. convexa* Say, 1822, has been used for narrow, strongly convex shells (Text-fig. 59B, F, G)
- *C. fornicata* covers broader convex shells that attach



Text-figure 59.—Gastropods with cup-shaped shells with an internal shelf. A–G. *Crepidula fornicata.* H. *Crepidula aculeata.*

themselves to wider surfaces than does *C. convexa* (Text-fig. 59A).

- *C. glauca* Say, 1822, includes broad shells of low convexity with white, unmarked outer surfaces.
- *C. maculosa* Conrad, 1846, has the same broad low shape of *C. glauca*, but it bears rows of reddish or brown spots (Text-fig. 59A).
- *C. plana* Say, 1822, was proposed for virtually flat shells but has also been used for the concave shape illustrated in Text-figures 59D and E.

All of these "species" are here included in *fornicata.* I have not simply grouped them all under the generic nomen *Crepidula* spp. because *C. aculeata* (Gmelin, 1791), an easily separable *Crepidula* with rows of cuplike spines on the shell, would also have to be included in *Crepidula* spp., but we recognized it as the distinct Amoco Taxon # 2004.

Comparison.—No other shell contains the flat umbonal platform of *Crepidula.*

Name.—*Crepidula fornicata* (Linnaeus, 1758).

Biofacies.—*Crepidula* is one of the Ubiquitous Taxa found in all biofacies except Rocky Shore and Grecian Rocks. It is most abundant in Northern and Central assemblages but less common in all others. It can be found in large numbers in isolated samples anywhere. It is never truly useful as a Key Taxon.

References.—(c = *convexa*) (f = *fornicata*) (g = *glauca*) (m = *maculosa*) and (p = *plana*). Warmke and Abbott, 1961, p. 87, pl. 15, figs. J–L (c, g, p); Morris, 1975, p. 164, pl. 45, figs. 8, 10–12 (c, f, m, p); Abbott, 1974, p. 141, figs. 1557–1559 (c, f, m); Rehder, 1981, pp. 464–466, figs. 412, 418, 420, 676 (c, f, m, p); Emerson and Jacobson, 1976, pp. 96–97, pl. XXI, fig 4 (c); pl. XXII, figs. 3–5 (f, m, p); Abbott and Dance, 1983, p. 72, figured (f, m).

TAXA MENTIONED IN THE DISCUSSION OF ARSNICKER DOME

The three nonmarine gastropods illustrated in Text-figures 60A–C are not common enough to serve as diagnostic forms, but they were important in interpreting the history of the uplifted Lower Arsnicker Keys.

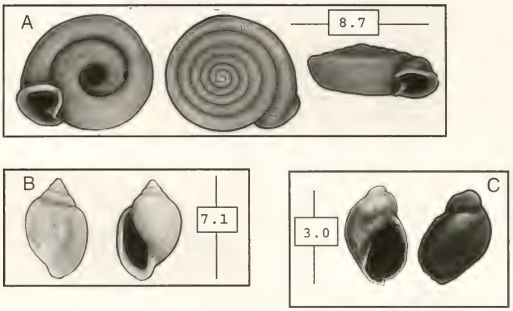
PELECYPODA

SURFACE SMOOTH EXCEPT FOR GROWTH LINES

Transennella conradina
Text-figure 61A, B

AMOCO Taxon #.—2152

Diagnosis.—Shells elongate with the anterior end rounded and the posterior end more pointed. Length greater than height. Beneath the beak in the right valve (Text-fig. 61A) there are two divergent cardinal teeth with a much smaller tooth on each side. Under the



Text-figure 60.—Nonmarine gastropods from Arsnicker Dome. A. *Polygyra volvoxis* Pfeiffer, 1846. B. *Physa heterostropha* (Say, 1817). C. *Pseudosuccinea columbella* Say, 1817.

beak of the left valve (Text-fig. 61B) there are grooves corresponding to the teeth of the right valve. In adult shells the margins on either side of the teeth bear obliquely incised striations (Text-fig. 63C). The interior of some well preserved shells can bear a pair of triangular purple flashes medially and a patch of the same color inside the posterior margin (Text-fig. 61B); however, most dead shells soon lose the color markings.

Comparison.—The overwhelming majority of these shells lack any sign of concentric structures other than growth lines. However, in the muddy lakes and bays along the edge of the Everglades some specimens develop ill-defined concentric undulations so that externally they mimic *Anomalocardia* or some *Polymesoda*. Ridging could be in response to living in soft mud, because some clams appear to find concentric ridges or frills make movement through muddy sediments easier. This mimicry is discussed more fully in the comments on *Anomalocardia* and *Polymesoda*, below. This shell needs to be contrasted with the following, with which it can be confused.

Name.—Transennella conradina (Dall, 1882).

Biofacies.—This is the most common mollusk in Florida Bay samples, accounting for 66% of the normalized specimen counts. It is the Dominant and Key Taxon for the Central Interior Biofacies. It is common in both Northern Subfacies and less common in the Central Exterior and *Lucina* faunas. It is a minor element in all other marine biofacies except the Rocky Shore and Grecian Rocks, from which it was not recovered.

References.—Morris, 1975, p. 63, pl. 26, fig. 2; Abbott, 1974, p. 529, fig. 5919; Emerson and Jacobson, p. 431, pl. 45, fig. 6.

Transennella stimpsoni
Text-figure 61C, D

AMOCO Taxon #.—2151

Diagnosis.—Like the preceding except being of subequal height and length and in having a rounded posterior profile instead of being pointed at the rear.

Comparison.—In typical adult shells, such as those shown here, the contrast between the two shapes is clear. In nature, the two taxa appear to form a continuum. This results in some specimens that are truly intermediate and difficult to separate. Fortunately, the majority of shells are easily separable, and the hard-to-place specimens are uncommon.

Name.—Transennella stimpsoni (Dall, 1884).

Biofacies.—Key Taxon in the *Lucina* and Gulf Biofacies. Minor elements of the Central and *Cerithium* faunas. Rare in other marine biofacies. Absent from the Rocky Shore fauna.

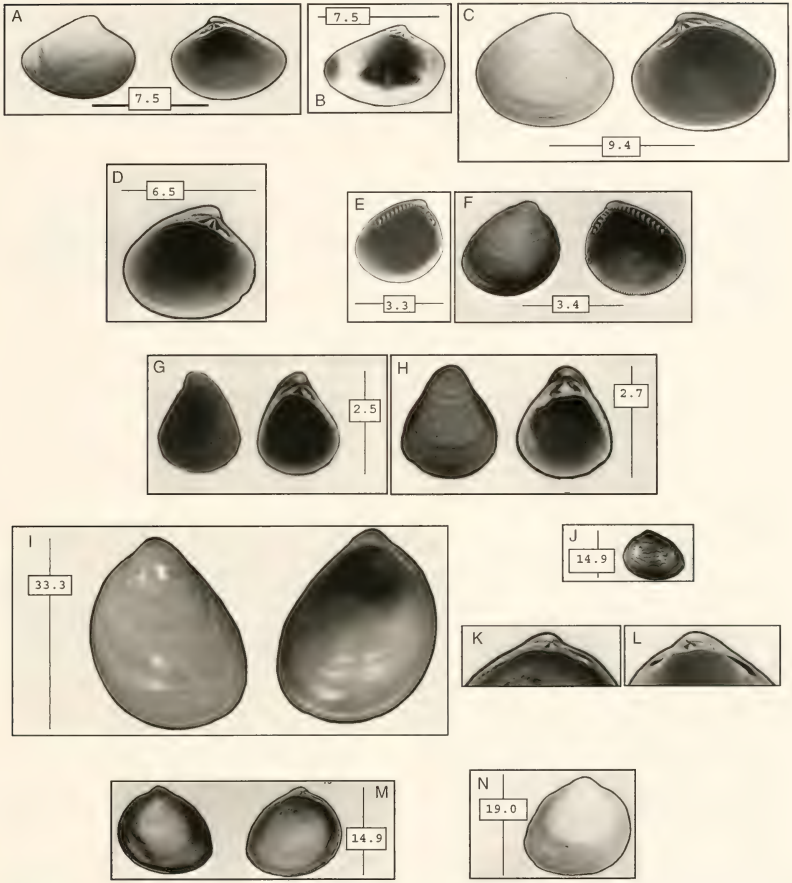
References.—Warmke and Abbott, 1961, p. 187, pl. 39, fig. A; Morris, 1975, p. 63, pl. 26, fig. 4; Abbott, 1974, p. 529, fig. 5918.

Nucula proxima
Text-figure 61E, F

AMOCO Taxon #.—2156

Diagnosis.—Nut-shaped shells to about 5 mm long. Marked by many similar platelike or slightly chevron-shaped teeth.

Remarks.—Teeth like those seen in this shell are called taxodont. They are not confined to *Nucula* and



Text-figure 61.—Pelecypods with smooth surfaces except for growth lines. A, B. *Transennella conradina.* C, D. *Transennella stimpsoni.* E, F. *Nucula proxima.* G, H. *Parastarte triquetra.* I–N. *Laevicardium laevigatum.*

its relatives but are found in many other taxa, some of which will be described below.

Comparison.—None of the other smooth shells has this combination of a small nut-like shape, smooth shell and taxodont dentition. Other shells with taxodont teeth described below are not smooth.

Name.—*Nucula proxima* Say, 1822.

Biofacies.—This shell is characteristic of the Gulf

Biofacies and is a little less common in the *Lucina* fauna. It is rare in all other marine biofacies and is absent from the Rocky Shore assemblage.

References.—Morris, 1975, p. 3, pl. 9, fig. 4; Abbott, 1974, p. 410, fig. 4786; Emerson and Jacobson, 1976, p. 340, pl. 37, fig. 1; Rehder, 1981, pp. 660–661, fig. 539; Abbott and Dance, p. 289, figured.

Parastarte triquetra
Text-figure 61G, H

AMOCO Taxon #.—2157

Diagnosis.—This is the smallest abundant clam in the Florida Bay faunas, rarely reaching a height of 3 mm. For its small size it has a thick, subtriangular shell, which is itself diagnostic. The right valve (Text-fig. 61H) has one large medial tooth with a socket on each side. The left valve (Text-fig. 61G) has two lateral teeth that fit into the sockets of the right valve.

Comparison.—No other shell is so small and subtriangular.

Name.—Parastarte triquetra (Conrad, 1846).

Biofacies.—The Dominant and Key Taxon in the Northern *Parastarte* Subfacies. Less common in the Northern *Anomalocardia* Subfacies. Rare in all other marine biofacies, except the Rocky Shore and Grecian Rocks, where it was not found.

References.—Warmke and Abbott, 1961, p. 190, pl. 39, fig. L; Morris, 1975, p. 67, pl. 24, fig. 8; Abbott, 1974, p. 534, fig. 5969; Emerson and Jacobson, 1976, p. 432, pl. 46, fig. 6; Abbott and Dance, 1983, p. 362, figured.

Laevicardium laevigatum
Text-figure 61I–N

AMOCO Taxon #.—2191

Diagnosis.—Shells polished, inflated, rather thin. Those from areas of dark muds in Florida Bay are streaked with brown and generally small (Text-fig. 61J). Shells from white sand areas, especially on the reef tract, are generally white and larger (Text-fig. 61I). Teeth are characteristic of cardiid shells, with a single triangular tooth in the right valve (Text-fig. 61L) and a socket bordered by lateral teeth in the left (Text-fig. 61K).

Comparison.—There are other cardiids in Florida Bay, but all are ribbed or otherwise ornamented.

Name.—Laevicardium laevigatum (Linnaeus, 1758).

Remarks.—This taxon, as used in this study, includes two named "species", *L. laevigatum* and the later *L. mortoni* (Conrad, 1831) (Text-fig. 61J, M–N). The features of *L.* "*laevigatum*" are its white color, larger size and more rounded outline (Text-fig. 61I). The characteristics of *L.* "*mortoni*" are the brown coloring, the smaller shells (Text-fig. 61J) and the more angular outline (Text-fig. 61M, which was coated for photography).

As an experiment, small shells of the *mortoni* type were placed directly on large *laevigata* specimens so that the shape of the two could be compared at the same size. When this is done there is no consistent difference in shape.

As for coloration, it appears to respond to the two sedimentary environments in which the two types are found. Thus, there appear to be no features that consistently divide these shells into two populations. Smaller shells are more angular, and larger shells are more rounded, but the smaller parts of large shells are angular.

Text-figure 61N is an unusually large *mortoni* (it has been coated but has brown speckled ornamentation) that is transitional to the *laevigatum* shape. It has nearly lost the posterior angle seen in Text-figure 61J and is approaching the curvature of Text-figure 61I. The area near the beak, marking the first half of the shell's growth has a more angular profile than the adult outer margin.

Biofacies.—One of the Ubiquitous Taxa, not diagnostic of a specific biofacies. Most common in *Lucina*, both Central and Gulf Biofacies; less so in other biofacies, except Rocky Shore and Grecian Rocks where it has not been found.

References.—(l = *laevigatum*, m = *mortoni)* Warmke and Abbott, 1961, p. 184, pl. 38, fig. E (l); Morris, 1975, pp. 56–57, pl. 23, fig. 9, 10 (l, m); Abbott, 1974, pp. 485–486, fig. 5572 (l, m); Emerson and Jacobson, 1976, p. 394, pl. 16, fig. 2, 3 (l, m); Rehder, 1981, p. 747, fig. 560 (l); Abbott and Dance, 1983, p. 331, figured (l, m).

SURFACE WITH RADIAL ORNAMENT

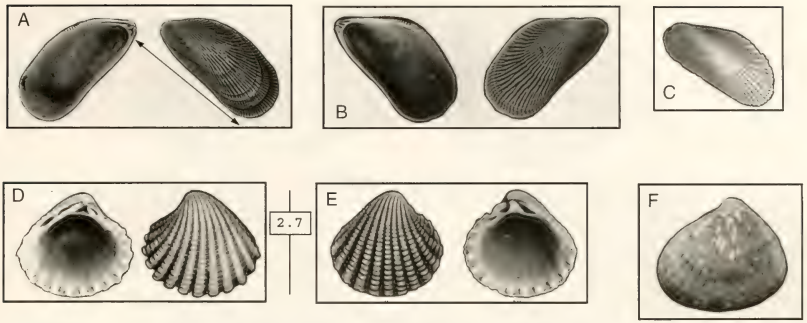
Brachidontes exustus
Text-figure 62A, B

AMOCO Taxon #.—2147

Diagnosis.—Oblique shells with regular ribs extending from the umbo (beak) to the posterior margin. Additional ribs can be intercalated as the shell grows larger (Text-fig. 62A, B). There are three small cardinal teeth in the beak (Text-fig. 62A, B).

Comparison.—Brachidontes modiolus (Linnaeus, 1767) (Amoco Taxon # 3043) (Text-fig. 62C) differs in having the umbo behind the anterior end of the shell. Also, the early portion of the shell is smooth, with the ribs developing one quarter to one third of the distance from the beak, depending on the length of the shell.

There are other shells with simlar oblique shapes, but none is ribbed.



Text-figure 62.—Pelecypods with surfaces bearing radial ornament. A. *Brachidontes exustus* (left valve). B. *Brachidontes exustus* (right valve). C. *Brachidontes modiolus*. D. *Pleuromeris tridentata* (left valve). E. *Pleuromeris tridentata* (right valve). F. *Pteromeris perplana*.

Name.—Brachidontes exustus (Linnaeus, 1758).

Biofacies.—The Dominant and Key Taxon in the Central Exterior Biofacies. It is second to, but much less common than, *Transennella conradina* in the Central Interior. It is moderately common in all other biofacies inside Florida Bay. Uncommon to rare in the *Caecum* Group. Not found in Gulf, Rocky Shore and Grecian Rocks Biofacies.

References.—Warmke and Abbott, 1961, p. 162, pl. 31, fig. F; Morris, 1975, p. 18, pl. 12, fig. 14, 19; Abbott, 1974, p. 429, fig. 5044; Emerson and Jacobson, 1976, p. 357, pl. 39, fig.1; Rehder, 1981, pp. 678–679, fig. 641 (as *Hormomya exusta*); Abbott and Dance, 1983, p. 298, figured.

Pleuromeris tridentata
Text-figure 62D, E

AMOCO Taxon #.—2520

Diagnosis.—Small inflated subtriangular shells with strongly beaded radial ribbing. Cardiid dentition, with a large cardinal tooth in the right valve with a corresponding deep socket in the left.

Comparison.—Easily confused in size and shape with *Pteromeris perplana* (Conrad, 1841) (Text-fig. 62F), but that shell has flattened radial ribs unlike the beaded ribs of *P. tridentata*.

Name.—Pleuromeris tridentata (Say, 1826).

Biofacies.—Most common in the Reef Tract Biofacies. Less common in *Tricolia*, Grecian Rocks, and Gulf Biofacies. Rare in other faunas except for the Northern Assemblages from which it was not recovered.

References.—Morris, 1975, p. 44, pl. 20, fig. 10 (as *Venericardia*); Abbott, 1974, p. 477, fig. 5489.

SURFACE WITH CONCENTRIC ORNAMENT

Anomalocardia auberiana
Text-figure 63A–B, D, G

AMOCO Taxon #.—2130

Diagnosis.—Subtriangular, concentrically ridged shells with the interior margins minutely denticulate. Most shells also bear a postumbonal groove (Text-fig. 63A, B, D).

Comparison.—It is frequently difficult to discriminate the exteriors of juvenile shells of *Anomalocardia* from those of *Transennella* or *Polymesoda* (below), but the internal margins are easily separable. The margin of *Anomalocardia* is denticulate (Text-fig. 63B); that of *Polymesoda* is smooth, and *Transennella* has oblique striations (Text-fig. 63C, arrow).

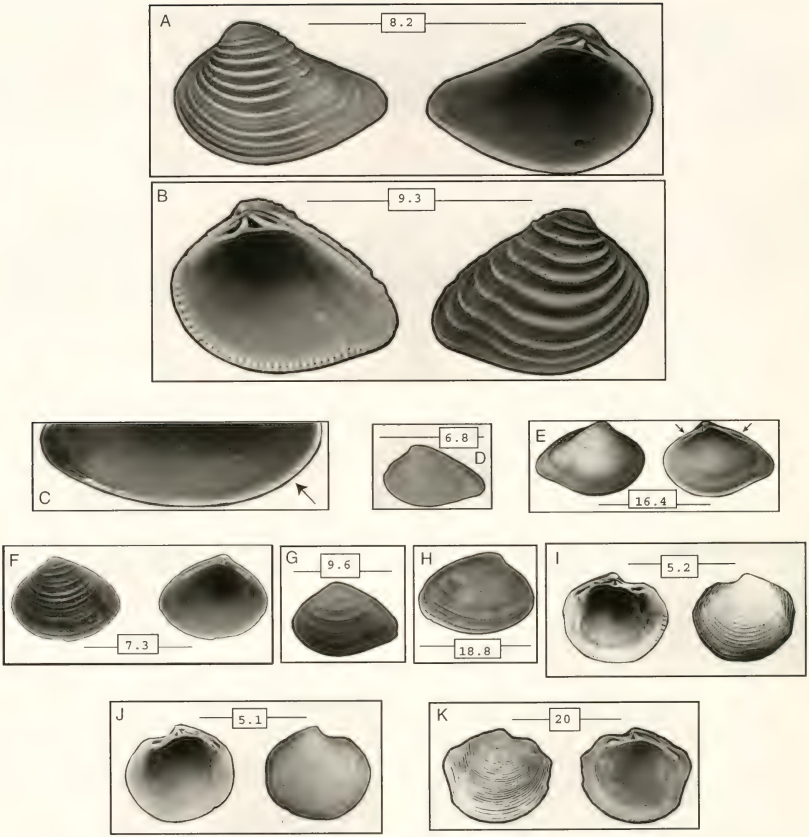
Remarks.—Rare specimens bear only faint concentric ridges (Text-fig. 63D), but the postumbonal groove and internal structures are unchanged.

There is considerable convergence among *Transennella, Anomalcardia* and *Polymesoda* exteriors. This is discussed more fully under *Polymesoda*.

Name. Anomalocardia auberiana (d'Orbigny, 1853).

Biofacies.—A Dominant Taxon in both Northern Biofacies, it is the Key Taxon in the *Anomalocardia* Subfacies. Fairly common in the Central Interior. Uncommon in Central Exterior and *Lucina* samples. Rare in the *Cerithium* and *Tricolia* Biofacies. Not recovered from the Reef Tract, Gulf, Rocky Shore or Grecian Rocks Biofacies.

References.—Abbott, 1974, p. 525, fig. 5887; Emerson and Jacobson, 1976, p. 432, pl. 46, fig.4; Rehder, 1981, p. 805, fig. 551.



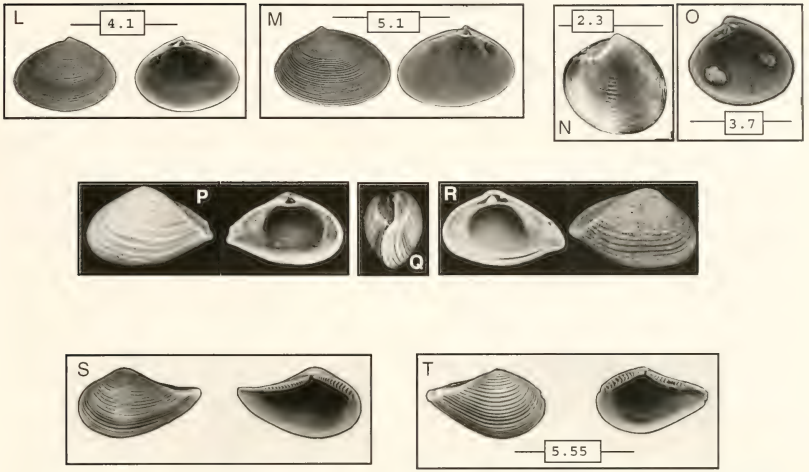
Text-figure 63.—Pelecypods with surfaces bearing concentric ornament. A–B, D, G, *Anomalocardia auberiana*. C, *Transennella* sp. E–F, H, *Polymesoda maritima*. I, J, *Parvilucina multilineata*. K, *Phacoides pectinatus*. (continued next page).

Polymesoda maritima
Text-figure 63E–F, H

AMOCO Taxon #.—2140

Diagnosis.—Generally ovate clams with variable surface features. Characterized by long narrow sockets lying along the dorsal margin of the right valve (Text-fig. 63E, arrows), into which the sharp edges of the left valve (Text-fig. 63F) are inserted.

Remarks.—*Polymesoda* cannot be readily identifiable from exterior features alone. The long narrow sockets of the right valve and the teeth that fit into them are the diagnostic features. The exteriors are



Text-figure 63.—Continued. L, M. *Ervilia concentrica.* N, O. *Transenella cubaniana.* P–R. *Corbula swiftiana.* S, T. *Nuculana acuta.*

most commonly smooth (Text-fig. 63E). Text-figures 63F and H show less common concentric ornament. The postumbonal groove seen in Text-figure 63E is quite uncommon. All of these variants resemble, closely but imperfectly, the exterior of *Anomalocardia.* In samples containing a preponderance of only one of the three shells, the exteriors of *Transennella* and *Polymesoda* tend to be smooth, while *Anomalocardia* is concentrically ridged. Where *Anomalocardia* occurs with common specimens of the other two shells the three forms tend to become homeomorphic with one another. Some *Anomalocardia* become somewhat effaced (Text-fig. 63G), thus converging on *Transennella,* or develop lamellar ornament similar to *Polymesoda* (Text-fig. 63H). In these same samples the normally smooth *Transennella* and *Polymesoda* can be found with low concentric ridges, aping *Anomalocardia.* As shown in Text-figure 63H, rare specimens of *Polymesoda* can appear to have an indistinct postumbonal groove that is characteristic of *Anomalocardia.* This close convergence makes it imperative that final identifications be confirmed by an examination of the internal structures.

Name.—*Polymesoda* (*Pseudocyrena*) *maritima* (d'Orbigny, 1853). The generic name has fluctuated between *Polymesoda* and *Pseudocyrena,* and the trivial name has alternated between *maritima* and *floridana,* proposed by Conrad in 1816. All combinations occur among the citations below.

Biofacies.—Most common in the Northern Biofacies and about equally abundant in both subfacies. Also washed into adjacent Everglades, Mud Flat and Playa samples. Uncommon in the Central Interior and Exterior Subfacies and the Gulf Biofacies. Rare in *Tricolia* Biofacies samples. Not seen elsewhere.

References.—Morris, 1975, p. 40, pl. 19, fig. 10; Abbott, 1974, p. 521, fig. 5851; Emerson and Jacobson, 1976, p. 424, pl. 42, fig. 16; Abbott and Dance, 1983, p. 352, figured.

Parvilucina multilineata
Text-figure 63I, J

AMOCO Taxon #.—2154

Diagnosis.—Minute lucinids with concentric ornamentation, thick shells and lacking a postumbonal groove. There is a single median tooth under the beak of the right valve (Text-fig. 63J) and a socket on the left. Lateral teeth are widely spaced in the right valve, with corresponding sockets on the left (Text-fig. 63I).

Comparison.—This is the smallest lucinid in Florida Bay. The most similar shell is *Phacoides pectinatus* (Gmelin, 1791) (Text-fig. 63K), but that shell is larger,

less inflated and has only a single strong anterior tooth in the right valve.

Name.—*Parvilucina multilineata* (Tuomey and Holmes, 1857).

Biofacies.—Abundant and the Key Taxon in the *Lucina* Biofacies. Uncommon to rare in all other marine biofacies except Rocky Shore and Grecian Rocks, from which it was not recovered.

References.—Morris, 1975, p. 47, pl. 21, fig. 10 (as *Lucina multilineata*); Abbott, 1974, p. 459, fig. 5290; Emerson and Jacobson, 1976, p. 381, pl. 40, fig. 4 (as *Lucina multilineata*); Rehder, 1981, p. 719, fig 719.

Ervilia concentrica
Text-figure 63L, M

AMOCO Taxon #.—3203

Diagnosis.—Minute shells 5–6 mm long, elongate-oval with beaks placed just to the rear of the center of the shell. The exterior bears fine concentric ridges that are minutely beaded on the best-preserved specimens. The teeth are complex for such a small shell. In the right valve there is a triangular muscle pit (resilifer) below the beak. There is a narrow cardinal tooth behind which a socket exists to receive the single bifid tooth of the left valve.

Comparison.—There are at least three other minute shells of similar shape to *E. concentrica,* but none has the complex teeth of this shell.

Name.—*Ervilia concentrica* (Holmes, 1860).

Biofacies.—Common in the Reef Tract and *Tricolia* Biofacies. Less common in *Cerithium* faunas. Rare in Gulf and southern Central Exterior samples. Not found elsewhere.

References.—Abbott, 1974, p. 493, fig. 5616; Emerson and Jacobson, 1976, p. 357, pl. 39, fig.1; Rehder, 1981, pp. 758–759, fig. 533.

Transennella cubaniana
Text-figure 63N, O

AMOCO Taxon #.—27119

Diagnosis.—Small *Transennella* up to 10 mm long, subequally long and high. Exterior marked by regular concentric ridges.

Comparison.—This species most resembles *T. stimpsoni* (above) in outline, but it is smaller and regularly, though minutely, ridged.

Name.—*Transennella cubaniana* (d'Orbigny, 1853).

Biofacies.—Common Key Taxon in Reef Tract faunas. Rare in the *Cerithium* and *Tricolia* Biofacies. Not found elsewhere.

References.—Warmke and Abbott, 1961, p. 187, pl. 39, fig. D; Morris, 1975, p. 63, pl. 26, fig. 1; Abbott, 1974, p. 529, fig. 5920.

Corbula swiftiana
Text-figure 63P–R

AMOCO Taxon #.—2132

Diagnosis.—Wedge-shaped shells 5–7 mm long. Heavy internal deposits. The right valve overlaps the left as seen in the posterior view of conjoined valves shown in the center photo. There is a single triangular cardinal tooth in the right valve and a corresponding deep socket in the left.

Comparison.—The only Florida Bay shell liable to confusion with this taxon is that described below, *Nuculana acuta* (Text-fig. 63S and T), but that shell has taxodont teeth and no massive internal deposits.

Name.—*Corbula swiftiana* C. B. Adams, 1852.

Biofacies.—The Key and Dominant Taxon in the Gulf Biofacies; it is uncommon in westernmost Northern *Parastarte* samples where Gulf influences are present, but it is not generally present in most of the subfacies. Rare in both Central Biofacies and in *Lucina, Cerithium* and *Tricolia* samples. Not recovered elsewhere.

References.—Warmke and Abbott, 1961, p. 207, pl. 43, fig. C; Morris, 1975, p. 92, pl. 31, fig. 12; Abbott, 1974, p. 539, fig. 6002; Abbott and Dance, 1983, p. 370, figured.

Nuculana acuta
Text-figure 63S, T

AMOCO Taxon #.—2136

Diagnosis.—Shells up to 10 mm long, with strong concentric ribbing, an acuminate posterior end, and taxodont dentition.

Comparison.—The acuminate posterior and taxodont dentition separate this from *Corbula swiftiana,* above. The concentric ribbing and acuminate posterior separate it from *Nucula proxima,* described earlier.

Name.—*Nuculana acuta* (Conrad, 1832).

Biofacies.—Characteristic of the Gulf Biofacies and fairly common in *Lucina* samples. Uncommon to rare in all other faunas except for Rocky Shore, where it was not recovered.

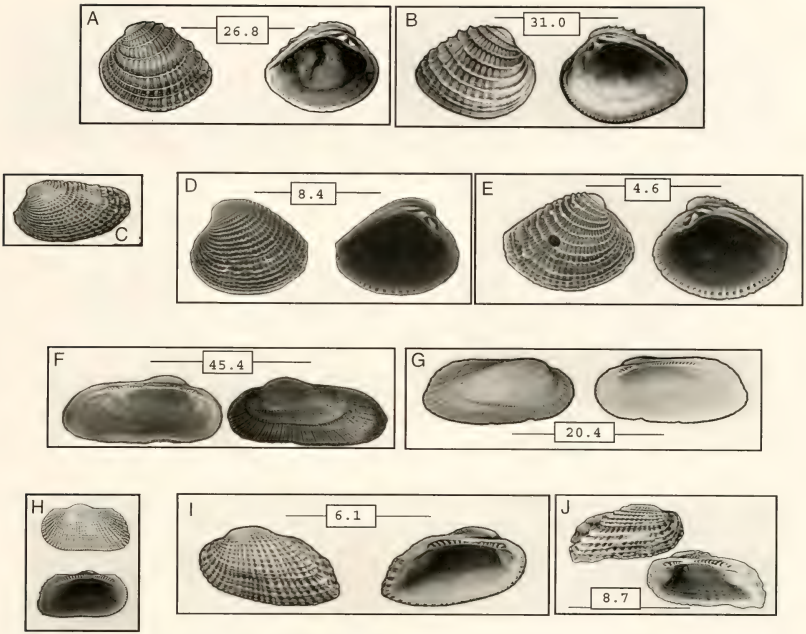
References.—Morris, 1975, p. 4, pl. 9, fig. 19; Abbott, 1974, p. 414, fig. 4858; Emerson and Jacobson, 1976, p. 342, pl. 37, fig. 2; Rehder, 1981, pp. 663–664, fig. 552; Abbott and Dance, 1983, p. 291, figured.

SURFACE WITH RADIAL AND CONCENTRIC ORNAMENT EQUALLY DEVELOPED

Chione cancellata
Text-figure 64A, B

AMOCO Taxon #.—2171

Diagnosis.—Subtriangular shells up to 40 mm long. Flat radial ribs mark the entire surface and are crossed



Text-figure 64.—Pelecypods with shell surfaces bearing radial and concentric ornament equally developed. A, B. *Chione cancellata.* C. *Chione floridana.* D, E. *Chione intapurpurea.* F, G. *Barbatia cancellaria.* H, *Arcopsis adamsi.* I, J. *Barbatia domingensis.*

by fringe-like concentric lamellae. The radial ribs commonly develop a median groove in larger specimens, especially on the anterior part of the shell. Two prominent cardinal teeth in the right valve and a single in the left.

Comparison.—"*Chione floridana*" (Text-fig. 64C) is elongate rather than subtriangular and has more closely spaced concentric lamellae. See also *C. intapurpurea* (Text-fig. 64D and E), discussed next.

Name.—*Chione cancellata* (Linnaeus, 1767).

Biofacies.—A Dominant Taxon in the Gulf Biofacies and also abundant in *Lucina* samples. Common in both Central Biofacies and in *Tricolia* assemblages. Has been found less commonly in all other biofacies except Rocky Shore and Grecian Rocks, from which it was not recovered.

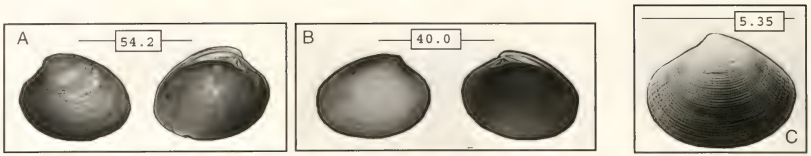
References.—Warmke and Abbott, 1961, p. 185, pl. 38, fig. O; Morris, 1975, pp. 59–60, pl. 25, fig. 2; Abbott, 1974, p. 523, fig. 5865; Emerson and Jacobson, 1976, p. 430, pl. 46, fig.1; Rehder, 1981, p. 803, fig. 501; Abbott and Dance, 1983, p. 365, figured.

Chione intapurpurea
Text-figure 64D and E

AMOCO Taxon #.—3221

Diagnosis.—Typical *Chione* with height and length subequal, up to 25 mm. The posterior of the shell tends to be truncate. Generally, the concentric lamellae are more closely spaced than in other *Chione*, but this is not universal, as the two illustrations show.

Comparison.—The subequal length and height differentiate this shell from the elongate *C. floridana*



Text-figure 65.—Pelecypod with surface bearing radial and concentric ornament unequally developed. A–C. *Mercenaria mercenaria.*

(Text-fig. 64C). The truncate posterior end of the shell separates it from both *C. cancellata* (Text-fig. 64A, B) and *C. floridana.*

Name.—Chione intapurpurea (Conrad, 1849).

Biofacies.—A Dominant Taxon in the Gulf Biofacies. Abundant in *Lucina* samples. Found in moderate numbers in all other biofacies except Rocky Shore and Grecian Rocks, from which it was not recovered.

References.—Warmke and Abbott, 1961, p. 186, pl. 38, fig. N; Morris, 1975, p. 59, pl. 25, fig. 1; Abbott, 1974, p. 523, pl. 24, fig. 5867; Emerson and Jacobson, 1976, p. 430, pl. 46, fig. 2.

Barbatia cancellaria
Text-figure 64E, G

AMOCO Taxon #.—2145

Diagnosis.—Elongate shells with taxodont dentition. Ribs are crossed by concentric grooving that interrupts the ribbing into rows of dots.

Comparison.—Barbatia domingensis (Text-fig. 64I, J), described below, has an angular outline and heavy, reticulate ornament.

Arcopsis adamsi (Dall, 1886) (Text-fig. 64H) is a smaller taxodont shell, 10–12 mm long, and is less oblique (its beak is nearer the midline of the shell).

Name.—Barbatia cancellaria (Lamarck, 1819).

Biofacies.—Most common in the Grecian Rocks Biofacies. Uncommon to rare in all other biofacies except the Northern and Rocky Shore Biofacies, where it was not found.

References.—Warmke and Abbott, 1961, p. 258, pl. 30, fig. J; Morris, 1975, p. 10, pl. 10, fig. 12; Abbott, 1974, pp. 421–422, fig. 4966; Emerson and Jacobson, 1976, p. 348, pl. 37, fig. 9; Abbott and Dance, 1983, p. 293, figured.

Barbatia domingensis
Text-figure 64I, J

AMOCO Taxon #.—2516

Diagnosis.—Taxodont shells up to 10 mm long with heavy, equally developed radial and concentric ribbing. The posterior ventral point of the shell is characteristically acute.

Comparison.—Unlike *B. cancellaria* (Text-fig. 64E, G), the radial ribs are not interrupted by the concentric ribs so the shell is heavily cancellate. The angular posterior ventral corner is unlike the rounded end of *B. cancellaria.* These same features separate this taxon from *Arcopsis adamsi* (Text-fig. 64H).

Name.—Barbatia domingensis (Lamarck, 1819).

Biofacies.—Common only in the Grecian Rocks Biofacies. Rare in both Central, *Cerithium, Tricolia,* Reef Tract and Gulf faunas. Not found elsewhere.

References.—Warmke and Abbott, 1961, p. 158, pl. 30, fig. D; Morris, 1975, p. 10, pl. 10, fig. 13; Abbott, 1974, p. 422, fig. 4967.

SURFACE WITH RADIAL AND CONCENTRIC ORNAMENT UNEQUALLY DEVELOPED

Mercenaria mercenaria
Text-figure 65A–C

AMOCO Taxon #.—2155

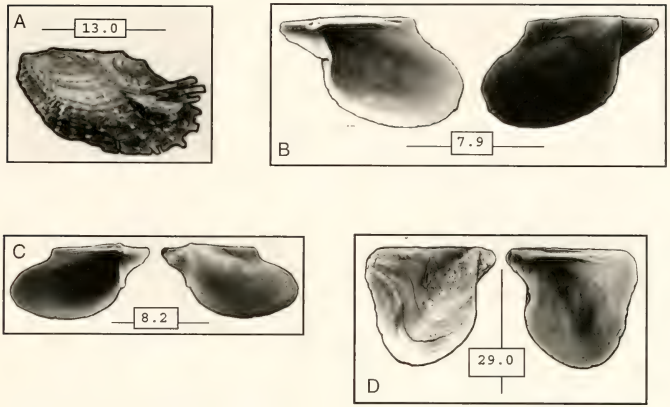
Diagnosis.—Large, typical clam shells. Two cardinal teeth in each valve; the anterior becoming elongate in large shells. The shell is basically ornamented with fine concentric lines over the entire surface, with additional fine radial ribs on both anterior and posterior ends. Large, worn shells generally have the ornamentation smoothed off (Text-fig. 65A, B), so the mix of ornament types is best seen on smaller shells (Text-fig. 65C). The posterior margin is slightly truncate.

Comparison.—The two-part ornamentation and the large size of the adult shells is distinctive.

Name.—Mercenaria mercenaria (Linnaeus, 1758).

Biofacies.—Common in the *Cerithium* Biofacies. Uncommon in *Lucina, Tricolia,* Reef Tract and Grecian Rocks samples. Rare in Central and Gulf faunas. Not found elsewhere.

References.—Morris, 1975, p. 59, pl. 1, fig. 6; pl. 24, 14; Abbott, 1974, p. 523, fig. 5861; Emerson and Jacobson, 1976, pp. 428–429, pl. 45, fig. 3; Rehder, 1981, p. 806, fig. 604; Abbott and Dance, 1983, p. 368, figured.



Text-figure 66.—Pelecypods with shell surfaces bearing spinose ornament. A–C. *Pinctada imbricata.* D. *Pteria* sp.

SURFACE WITH SPINOSE ORNAMENT

Pinctada imbricata
Text-figure 66A–C

AMOCO Taxon #.—2165

Diagnosis.—Fragile, nacreous shells, to 25 mm long at the hinge. Internally, there is a strong vertical ridge below the umbo. Intact shells bear rows of flat radial spines (Text-fig. 66A), but because of their fragility the usual specimen is smooth (Text-fig. 66B, C).

Remarks.—Of the many hundreds of these shells found in our samples, the specimen shown in Text-figure 66A was the only one that retained a significant number of the radial spines. An oblique smooth shell, a prominent anterior "ear" in front of the umbo, and a vertical ridge below the umbo inside are the distinguishing features.

Because of its fragility this shell breaks readily into many small pieces. Samples collected from sediments where *Pinctada* is present in any numbers sparkle with myriad minute green-to-yellow flakes of broken shell. The numbers of these flakes give a false impression of the abundance of *Pinctada.*

Comparison.—*Pteria* sp. (Text-fig. 66D) has an outline that is much like that of *Pinctada,* but *Pteria* lacks the internal vertical ridge below the beak.

Name.—*Pinctada imbricata* Röding, 1798. The name *Pinctada radiata* (Leach, 1814), has been widely used for this shell in the past, and the older name has only recently become accepted.

Biofacies.—Common in the Gulf and *Lucina* Biofacies. Less common in Northern *Parastarte,* Central Exterior, *Cerithium* and *Tricolia* samples. Rare in all others except Rocky Shore, where it was not seen.

References.—Warmke and Abbott, 1961, p. 166, pl. 32, fig. B; Morris, 1975, p. 25, pl. 15, fig. 1; Abbott, 1974, p. 440, fig. 5122; Emerson and Jacobson, 1976, p. 364, pl. 44, fig. 2; Rehder, 1981, pp. 689–690, fig. 653; Abbott and Dance, 1983, p. 302, figured.

Text-figure 67.—Pelecypod with shell surface bearing frilly, lamellose ornament: *Chama florida.*

SURFACE WITH FRILLY, LAMELLOSE ORNAMENT

Chama florida
Text-figure 67

AMOCO Taxon #.—3253

Diagnosis.—All chamids are attached to the substratum by one valve or the other, and in this taxon the "upper" valve is the right valve. The "lower" or

Table 7.—Critical Bingo Board taxa, with Amoco Taxon numbers.

2605	*Hydrobia totteni*
2482	Gastropod 2482
2157	*Parastarte triquetra*
2483	*Truncatella*
2130	*Anomalocardia auberiana*
2040	*Retusa candei*
2152	*Transennella conradina*
2114	*Cerithidea costata*
2091	*Cerithium muscarum*
2147	*Brachidontes exustus*
2096	*Diastoma varia*
2154	*Parvilucina multilineata*
2093	*Cerithium atratum*
3221	*Chione intapurpurea*
2013	*Tricolia affinis*
2102	*Vermicularia spirata*
2009	*Modulus modulus*
2094	*Cerithium algicola*
3042	*Finella dubia*
2132	*Corbula swiftiana*
2171	*Chione cancellata*
2151	*Transennella stimpsoni*
2156	*Nucula proxima*
2136	*Nuculana acuta*

attached valves of all chamids are uncommonly recovered, and in the case of *C. florida* none suitable for photography was found. Taxa are separated based on the coiling of the beak (clockwise in *C. florida*) and on the position of the beak (on the periphery of the valve, or within it, as in *C. florida*).

Comparison.—All chamids have the same significance in identifying the biofacies of samples. *C. florida* was the most commonly recovered chamid, so it was chosen to represent the whole group.

Name.—*Chama florida* Lamarck, 1819.

Biofacies.—Uncommon in the Reef Tract Biofacies. Rare in Grecian Rocks. *Tricolia* and *Cerithium* samples. Not found elsewhere.

References.—Warmke and Abbott, 1961, p. 180, pl. 37, fig. E.

APPENDIX 2: THE BINGO BOARD

The Bingo Board provides a tool that permits any worker in Florida Bay to identify in the field which biofacies has been sampled. The Board is not a substitute for detailed, quantitative analysis using FACICALC, but it is a workable field technique.

The weighting system used on the Board is based on decile values of each taxon in each biofacies. The decile values are based on the reference samples used in FACICALC as standards for each biofacies. The normalized count for each taxon in the reference samples was divided by the normalized count of the most abundant taxon in the reference samples. The most abundant taxon has, by definition, a decile value of 10, with all other taxa receiving proportionate values.

Table 8.—Freshwater taxa that can be added to the Bingo Board, with Amoco Taxon numbers.

TAXA	NO.	MUD FLAT	PLAYA
Hydrobia totteni	2605	10	
Gastropod 2482	2482	7	
Cerithidea costata	2114		9
Polymesoda maritima	2140		10
Diastoma varia	2096		10

Taxa not having a decile value of three or higher in at least one reference sample are omitted from the Board. However, for taxa passing this threshold in at least one biofacies, all decile values above 1 are listed.

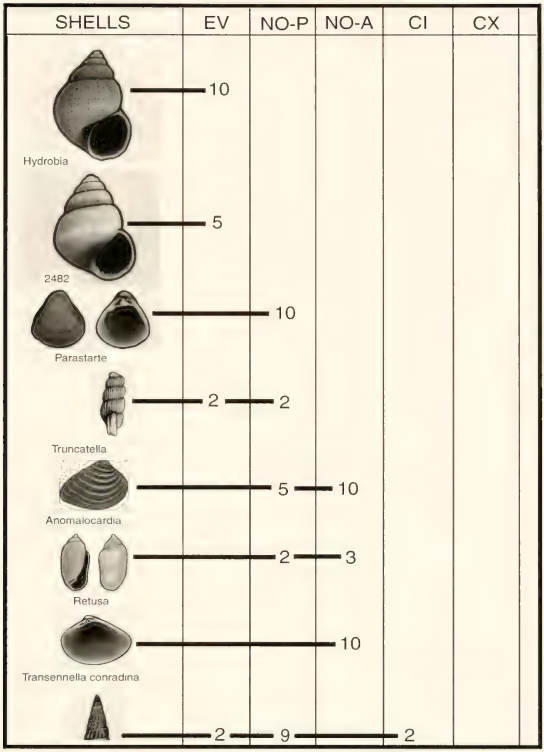
The Bingo Board is designed for use with surface samples taken in the field. If decile values give ambiguous results, the sample is likely to be transitional between biofacies and true specimen counts should be made.

As a field tool the Bingo Board is unnecessary if the provenance of a sediment sample is obvious. For example, there is no need for a Board analysis to show that the Playa Biofacies is present if the sample came from the surface of a playa. For similar reasons it is superfluous to identify Everglades, Mud Flat, Rocky Shore or Grecian Rocks Biofacies with the Board. A Board containing columns for all biofacies would be impractically wide and cumbersome.

The reef tract poses a special problem. Most samples from the outer reef tract, offshore of the Florida Keys yield the Reef Tract Biofacies, but closer inshore the *Cerithium* and *Tricolia* Biofacies emerge from the Bay and are developed along the outer side of the Keys (Text-fig. 13).

For these practical reasons the normal Bingo Board will carry the seven columns—Northern *Parastarte* through *Tricolia*—shown in Table 9.

Although the Board layout illustrated in Text-figure 68 is probably the most useful for most sampling in Florida Bay, a listing of the critical taxa for all biofacies is presented in Table 7. With the full list, any customized Bingo Board can be constructed as needed. The order of the taxa is designed to group them in the progression seen from the Everglades outward. Using the taxa in this order will make the answer to the ques-



Text-figure 68.—Upper left corner of one form of the Bingo Board, with thumbnail illustrations down the left side and the decile values (2 or above) for each taxon in one or more biofacies.

tion, "Which biofacies is this sample from?" develop most quickly in the field.

THE BASIC LAYOUT

The biofacies and taxa shown in Table 9 are those normally useful for discriminating marine biofacies within the Bay. In practice, most traverses made by seminars are made east of the longitude of the Black Betsy Keys and Twin Key Bank. For such examinations the columns for the Gulf and Northern *Parastarte* Biofacies can be omitted, making more room for each remaining column. If the northern bays are not open to public access, and Everglades faunas are not expected, that column can also be omitted.

On the other hand, if the traverse is to include visits to the playas and mud flats, columns for those two quasimarine biofacies can be added although identification of those two biofacies on the surface is self-evident. The taxa to be added for those two columns are shown in Table 8.

Text-figure 68 shows the upper left corner of one form of the Bingo Board, with thumbnail illustrations

down the left side and the decile values (2 or above) for each taxon in one or more biofacies.

APPENDIX 3. RATIOS OF PELECYPOD VALVES

Tables 10–12 contain data on the number of oriented pelecypod valves counted during this study. The numbers are true counts and have not been normalized. Clam shells appear most commonly as separated right or left valves. Less common are specimens in which the two valves remain in contact, as in life. These are listed as "entire".

All three tables list the number of entire specimens and separated right and left valves. The column titled "Total" is the sum of the columns "Right" and "Left" plus an additional right and left valve for each entire specimen. All three tables are arranged in descending order of the "Total" numbers.

Table 10 lists the taxa for which more than 200 specimens were counted. Chi-square tests showed that all taxa in Tables 10 and 11 do not significantly differ from a 50–50 ratio when adjusted for numbers of specimens. The addition or subtraction of a single specimen does not alter the ratios in samples of more than 200, whereas in smaller samples a single right or left valve could do so. Table 11, containing the less-well-sampled taxa is added for completeness.

Table 12 includes those shells that have one valve attached in some way and *Pinctada*, whose two valves are known to differ in shell microstructure. Exclusion of such shells is warranted because the asymmetry of their ratios is related to factors other than postmortem sorting and transportation.

Table 9.—Basic Bingo Board layout.

TAXA	EV	NO-P	NO-A	CI	CX	LU	CE	TR	GU
2605	10								
2482	5								
2157		10							
2483	2	2							
2130		5	10						
2040		2	3						
2152				10					
2114	2	9		2					
2091			3	3					
2147			3	2	10				
2096			3	4	4				
2154						10			
2093							10	2	
3221							3		
2013							3	10	
2102							6	2	
2009								2	
2094								3	
3042								3	
2132									10
2171									8
2151						3			7
2156						3		2	4
2136									4

Table 10.—Pelecypod taxa with counts above 200.

TAXA	Entire	Right	Left	Total	% Right	% Left
Transennella conradina	1,167	31,522	31,340	65,196	50	50
Brachidontes exustus	373	12,230	12,206	25,182	50	50
Anomalocardia auberiana	249	10,634	10,396	21,528	51	49
Laevicardium laevigatum	110	8,422	8,036	16,678	51	49
Transennella stimpsoni	283	7,248	7,111	14,925	50	50
Parastarte triquetra	765	5,670	5,725	12,925	50	50
Chione cancellata	102	4,721	4,682	9,607	50	50
Polymesoda maritima	21	3,147	2,861	6,050	52	48
Tellina texana	106	2,659	2,544	5,415	51	49
Parvilucina multilineata	153	2,250	2,266	4,822	50	50
Tellina mera	74	2,180	2,171	4,499	50	50
Carditamera floridana	57	1,812	1,776	3,702	50	50
Cumingia tellinoides	39	1,366	1,460	2,904	48	52
Nuculana proxima	177	1,227	1,151	2,732	51	49
Codakia orbiculata	61	1,186	1,132	2,440	51	49
Chione intapurpurea	35	1,115	1,151	2,336	49	51
Lucina nassula	35	1,150	1,091	2,311	51	49
Arcopsis adamsi	28	728	713	1,497	51	49
Mercenaria mercenaria	35	666	666	1,402	50	50
Corbula swiftiana	11	601	462	1,085	56	44
Lima inflata	0	496	407	903	55	45
Cyrenoida floridana	0	377	329	706	53	47
Brachidontes modiolus	8	329	342	687	49	51
Ervilia concentrica	59	268	276	662	49	51
Tellina similis	14	321	279	628	53	47
Crenella divaricata	12	285	262	572	52	48
Nuculana acuta	22	244	225	513	52	48
Argopecten gibbus	3	261	226	493	54	46
Tagelus conradi	1	256	212	470	55	45
Mytilopsis leucophaeata	1	174	193	369	47	53
Abra aequalis	0	208	158	366	57	43
Pleuromeris tridentata	22	152	131	327	53	47
Glycymeris pectinata	7	165	124	303	57	43
Barbatia cancellaria	9	144	125	287	53	47
Glans dominguensis	32	79	91	234	47	53
Transennella cubaniana	3	122	100	228	55	45
Mysella planulata	17	95	97	226	50	50
"Lepton" 3205	6	104	104	210	48	52
TOTALS	4,126	105,024	103,044	216,320	50	50

Table 11.—Pelecypod taxa with counts less than 200.

TAXA	Entire	Right	Left	Total	% Right	% Left
Modiolus americanus	4	75	73	156	51	49
Lyonsia floridana	1	58	59	119	50	50
Tagelus divisus	0	61	56	117	52	48
Trachycardium muricatum	1	51	60	113	46	54
Americardia guppyi	0	57	44	101	56	44
Arca zebra	6	46	36	94	55	45
Barbatia domingensis	6	46	36	94	55	45
Abra lioica	1	49	39	90	56	44
Aequipecten muscosus	1	41	42	85	49	51
Musculus lateralis	3	31	46	83	41	59
Noetia ponderosa	0	27	37	64	42	58
Mactra fragilis	1	32	29	63	52	48
Diplodonta punctata	2	24	33	61	48	57
Cumingia coarctata	1	28	30	60	48	52
Arca imbricata	4	23	27	58	47	53
Americardia media	0	31	25	56	55	45
Linga amiantus	2	24	22	50	52	48
Papyridea soleniformis	3	20	23	49	47	53
Crenella glandula	3	20	23	49	47	53
Linga pensylvanica	5	18	20	48	48	52
Lucina blanda	1	19	25	46	43	57
Periglypta listeri	1	17	27	46	39	61
Trachycardium isocardia	0	26	17	43	60	40
Lucina pectinata	2	21	17	42	55	45
Semele proficua	0	27	13	40	68	33
Anodontia alba+philippiana	4	14	17	39	46	54
Tellina candeana	0	21	16	37	57	43
Lyropecten antillarum	0	24	12	36	67	33
Erycina emmonsi	2	16	14	34	53	47
Pteromeris perplana	1	11	15	28	43	57
Limatula subauriculata	2	15	9	28	61	39
Dosinia elegans	0	12	14	26	46	54
Chione pygmaea	0	14	10	24	58	42
Pteria colymbus	1	8	11	21	43	57
Anadara notabilis	0	13	7	20	65	35
Crassinella lunulata	3	7	6	19	53	47
Papyridea semisulcata	0	7	11	18	39	61
Cyrtopleura costata	0	5	8	13	38	62
Lucina floridana	0	5	4	9	56	44
Mulinia lateralis	0	3	0	9	33	67
Isognomon radiata	0	6	3	9	67	33
Cardiomya perrostrata	1	5	2	9	67	33
Solen viridis	0	6	2	8	75	25
Raeta plicatella	0	4	2	6	67	33
Tellina listeri	0	5	1	6	83	17
Semele bellastriata	1	3	1	6	67	33
Papyridea soleniformis	0	2	3	5	40	60
Amusium papyraceum	0	3	2	5	60	40
Lima lima	0	2	2	4	50	50
Psammotreta intastriata	0	4	0	4	100	0
Chlamys sentis	0	1	3	4	25	75
Dinocardium vanhyningi	0	2	1	3	67	33
Arcopagia fausta	1	1	0	3	67	33
Aligena texasiana	0	2	1	3	67	33
Orobitella elevata	0	2	1	3	67	33
Atrina rigida	0	1	1	2	50	50
Thyasira trisinuata	0	1	1	2	50	50
Lima scabra	0	2	0	2	100	0
Gastrochaena cuneiformis	0	1	1	2	50	50
Basterotia 3216	0	0	1	1	0	100
Verticordia ornata	0	1	0	1	100	0
TOTALS	59	1,117	1,084	2,319	51	49

Table 12.—Pelecypod taxa with non-uniform valves.

TAXA		Entire	Right	Left	Total	% Right	% Left
RIGHT VALVE ATTACHED							
Anomia simplex		1	2	303	307	1	99
Pseudochama radians		0	4	11	15	27	73
	TOTALS	1	6	314	322		
LEFT VALVE ATTACHED							
Lopha frons		0	169	122	291	58	42
Crassostrea rhizophorae		0	123	75	198	62	38
Chama florida		3	40	4	50	86	14
Chama sinuosa		0	7	2	9	78	22
Chama macerophylla		0	4	3	7	57	43
	TOTALS	3	343	206	555		
RIGHT VALVE WEAKER							
Pinctada imbricata		13	2,122	2,370	4,518	47	53

APPENDIX 4: KEY TO TAXA

GASTROPODA

Cap-shaped or pyramidal
Acmaea antillarum (2088)
Narrow, high-spired gastropods with siphonal notch at lower left of aperture
Batillaria minima (2090)
Diastoma varia (2096)
Narrow, high-spired gastropods with siphonal notches at lower left and upper right of aperture
Cerithium muscarum (2091)
Cerithium atratum (2093)
Cerithium litteratum (2095)
Cerithiopsis greenii (2098)
Aperture without siphonal notches
Finella dubia (3042)
Cerithidea costata (2114)
Truncatella (2119, 2120 & 2483)
Rissoina bryerea (2117)
Rissoina fischeri (26689)
Trochoid gastropods with large body whorls and smooth adult surfaces
Littorina ziczac (3032)
Hydrobia totteni (2605)
Gastropod 2482
Tricolia affinis (2013)
Trochoid gastropods with large body whorls and adult surfaces ornamented
Alvania auberiana (3281)
Tectarius muricatus (2073)
Modulus modulus (2009)
Vertically subcylindrical gastropods with vertically elongate aperture and apex visible
Retusa candei (2040)
Marginella carnea (3035)
Vertically ovate gastropods with depressed (hyperstrophic) apex
Bulla striata (2033)
Gastropods with minute arcuate shells
Caecum pulchellum (2079)
Caecum nitidum (2080)
Caecum cornucopiae (3280)
Gastropods with irregularly uncoiled shells
Vermicularia spirata (2102)
Gastropods with a cup-shaped shell with an internal shelf
Crepidula fornicata (2001)

PELECYPODA

Surface smooth, except for growth lines
Transennella conradina (2152)
Transennella stimpsoni (2151)
Nucula proxima (2156)
Parastarte triquetra (2157)
Laevicardium laevigatum (2191)
Surface with radial ornament
Brachidontes exustus (2147)
Pleuromeris tridentata (2520)
Surface with concentric ornament
Anomalocardia auberiana (2130)
Polymesoda maritima (2140)
Parvilucina multilineata (2154)
Ervilia concentrica (3203)
Transennella cubiana (2119)
Corbula swiftiana (2132)
Nuculana acuta (2136)
Surface with radial and concentric ornament equally developed
Chione cancellata (2171)
Chione intapurpurea (3221)
Barbatia cancellaria (2145)
Barbatia domingensis (2516)
Surface with radial and concentric ornament usually developed
Mercenaria mercenaria (2155)
Surface with spinose ornament
Pinctada imbricata (2165)
Surface with frilly, lamellose ornament
Chama florida (3253)

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